ESSAYS ON INSTITUTIONAL COMPLEMENTARITIES, ORGANIZATIONAL FORMS AND KNOWLEDGE ECONOMY

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THESIS ABSTRACT

The thesis studies the interplay between technology and property rights in the production organization. In particular, we analyze the *complementarities* between these two domains. The first paper (Chapter 1) studies the concept of *organizational forms*, whose foundation is crucially based on the idea of institutional complementarities in the production organization. We point out that when the effect of property rights is not taken into account, technology alone entails unique solution to the problem of production organization. We claim that: (a) the asymmetry between the characteristics of labour and capital under the existing property relations, and (b) the importance of workers' preferences for different ways of production organization, should be taken into account when studying the organization of production. In so doing, we show that efficiency driven arguments on the relative success of different organizational forms are flawed. Therefore, progress in production organization should be described not as a linear path, but as a branching tree.

The second paper (Chapter 2) applies the very same framework to the case of the knowledge economy. In other words, it attempts to provide an analytical framework to analyze organizational forms in the knowledge economy. By recourse to a formal model, we study the determinants of the distribution of alternative institutional arrangements in the knowledge economy. We argue that organizational ecology is mainly determined by knowledge network effects, and complementarities between intellectual property rights (IPRs) and technology.

The last chapter (Chapter 3) is a short run view on the same issue. It studies the choice of alternative IPRs regimes and technology in business firms, taking into account their effects on the knowledge workers' skill acquisition. We argue that, at least in part, it has been the rising economic importance of knowledge that has brought an overreaching enclosure movement on it. Yet, IPRs regime

protecting the knowledge base of firms may deprive knowledge workers of owning the intellectual assets developed in the production process. This development, in turn, (a) has damaging consequences on the knowledge workers' skills; thereby (b) the rise of a virtuous cycle between non-exclusive property rights and workers' skills is prevented.

CHAPTER 1

INSTITUTIONAL COMPLEMENTARITIES AND ORGANIZATIONAL FORMS

Abstract

This paper analyses the concept of *organizational forms*, and derives some implications for the economics of production organization. To this end, after pointing out the role of knowledge in the organization of production, we discuss the theories based on technology (new institutional economics) and property rights (so-called radical school). When the effect of property rights is not taken into account, technology alone entails unique solution to the problem of production organization. After ruling out this technologically deterministic argument, by recourse to a simple model, we study the *complementarities* between these two domains. Finally, we derive some implications: (a) the asymmetry between the characteristics of labour and capital under the existing property relations, (b) the importance of workers' preferences for different ways of production organization. In so doing, we show that efficiency driven arguments on the relative success of different organizational forms may be misleading. Hence, we argue that, change in production organization should be described not as a linear path, but rather as a branching tree.

JEL Codes: D23, J54, L23, P14

Keywords: technology, transaction costs, property rights, institutional complementarities, organizational forms

1. Introduction

Technology is knowledge utilized in the production of goods and services. It is central to every economic activity. This centrality, sometimes, is taken to the extreme that every major social change is solely explained by technological change. The opponents of this view, rightly, accuse technology-driven

explanations as being determinist, i.e. technological determinism. Technological change does not occur in a vacuum. To put it in another way, there is technological *potentiality* not *determinism*.[1] Technological change sets the limiting conditions of what is possible. It defines the possible, and does not solely determine which choices are taken up.

Power relations and property rights are of great importance for the evolution of technology, since those who control the resources are able to choose the one most favourable to their interest from the available technologies. Yet, the evolution of technology cannot fully be shaped by the existing power relations and property rights. The prospects of advances in technological knowledge are not necessarily predictable. Hence, the opposite extreme, i.e. property rights determinism, is also flawed.

By focusing on the interplay between these two forces, we abandon the notion of production as a natural process, and place it into a framework where the organization of production is seen as a *social* phenomenon. The standard approach assumes complete contracts and zero transaction costs. As Samuelson (1957) put it, 'in a competitive economy it really does not matter who hires whom.' This framework, however, does not allow for a discussion in which technology and property rights influence each other: When it is impossible to write complete contracts, i.e. when there are positive transaction costs, the characteristics of productive forces are likely to influence the type of (control) rights that prevail and vice versa.

In the paper, we claim that whereas bounded rationality and incomplete contracts are necessary ingredients for the theory of the firm, it is the notion of institutional complementarities and multiple organizational equilibria that constitute the foundations of an approach upon which different institutional arrangements of production could be built. In doing so, we show that simple efficiency arguments on the relative success of different organizational forms

[1] Stating the issue in terms of 'potentiality versus determinism' is inspired by Stephen J. Gould. In Gould, the discussion is on 'biological potentiality versus genetic (or biological) determinism' (Gould 1977, Chapter 32).

may be misleading. Thereby, organizational evolution should be depicted as a branching tree rather than a unique linear path.

Any type of organization, including the firm, has to deal with the limits of human knowledge. The role of knowledge in production organization is discussed in Section 2. We then analyze the new institutionalist program that stresses the role of technology in determining efficient property rights regimes (Section 3). Taking into account the opposite direction of causality is the theme of Section 4. Co-determination of technology and property rights, and the *complementarities* between the two are studied in detail in Section 5.[2] Finally, in Section 6, we point out the main implications of our analysis. Section 7 concludes.

2. Knowledge and the Firm

Production is ultimately a knowledge-based activity. There is no production without technological knowledge. The study of this vital element has always been a challenging task in economic theory.[3] In this section, we study the organizational characteristics of technological knowledge, in which relations within business units are the focus of attention. In any organization, knowledge required for producing a product is not available in its totality, and is distributed across many individuals; when and how it is utilized in the production process is of great importance.

The nature of technology reflects itself on the way production is organized. As Veblen (1914) pointed out long ago, 'the life history of man is the life history of human community'. There is no technological knowledge without (industrial) community. In other words, production and technological change are group phenomena. This is so since the limitations of human capacities for receiving and processing information necessitate sharing problems that are difficult for a

[2] This interplay constitutes the core of the Marxian theory of history. See, for example, Cohen (1978), and Brenner (1986).

[3] See Metcalfe (2010) for an overview of different approaches.

single person to handle (Loasby 1976). It is only because humans are limited in knowledge, skill and time that organizations are useful for the achievement of human purpose. In essence, human beings are intendedly rational but only *boundedly* so (Simon 1997). Organizations are devices which cope with the limits of man's abilities to compute in the presence of complexity (Simon 1979).

Bounded rationality implies that under complexity, decision makers look for a *satisficing* rather than an optimal solution (Simon 1955). In such an environment, habits and routines conserve scarce and costly decision making time in production. These habits and routines are based on experience and practice that are difficult to transmit in nature. In other words, technological knowledge is not totally articulated, and it is the *tacit* dimension that underlies skilful performance (Nelson and Winter 1982, 73).[4]

This unarticulated (tacit) knowledge is stored in skills and capabilities of organizations as well as individuals. For that reason, organizations' activities are likely to proceed according to established routines, and the establishment of such routines is itself a rational behaviour (Simon 1997, 89). Individuals may come and go but organizations do remain. Capabilities that enable the organization to produce are not directly accessible to any single person. In other words, the capabilities of an organization are not a mere sum of individual capabilities of its members. Thereby, possession of any technological knowledge is also an attribute of the firm as an organized entity (Nelson and Winter 1982, 63). The necessary knowledge for producing goods and services resides in organization's memory, and the way to remember it is by *doing*, i.e. routinization of productive activity in the organization (Nelson and Winter 1982).

[4] This is the well known distinction between *know how* and *know that* (Ryle 1949). Know that corresponds to easy to codify knowledge. Know how, on the other hand, refers to skills and capabilities that are tacit in nature. Importantly, tacit knowledge is acquired experientially, and transferred by personal instruction, or by the provision of expert services (Dasgupta and David 1994, 494; Polanyi 1958, 1967). Vincenti (1990) provides an excellent historical analysis of the role of tacit knowledge in the aeronautical industry. Friedrich Hayek (1937, 1945) stressed the role of tacit knowledge in a market economy. The costly nature of acquiring and transferring tacit knowledge is related to what Pagano (2000) calls bounded communication skills.

Modern organizations with their hierarchical structures are adaptive forms for bounded rationality of agents under complexity (Simon 2002). As Simon (1962, 468) argues, administrative hierarchy is one of the most important structures that complexity uses. Yet, even though hierarchy exists both in natural and social realms, distinct from the former, in hierarchical social systems there are subordination and authority. The problem of ownership and control rights inside an organization touches upon this aspect of production organization, i.e. organizations are coalition of agents with different rights, interests and motivations. The new institutionalist approach argues that technology is paramount in determining ownership and control rights in the organization.

3. Technology and the New Institutionalist Program

In the new institutionalist literature,[5] existing forms of production organization and ownership relations reflect efficient responses to the nature of assets employed, i.e. technology. The first branch of new institutionalism, i.e. the property rights approach, argues that it is the *monitoring* characteristics of the assets that determine efficient production organization. Their approach, as they claim, moves Coase towards the goal of explaining the conditions under which managing resources in the firm is less costly than allocating them through the market (Alchian and Demsetz 1972, 784).

In particular, the firm exists due to the team nature of production: It makes difficult to determine marginal contributions of each agent and the firm hierarchy (that assigns a monitoring function to an agent) is a remedy to it. Hierarchy mitigates the problem of monitoring where the monitor becomes residual claimant.[6] As such, the firm is seen as a specialized set of market contracts, in which the role of authority relations is rejected (Jensen and Meckling 1976). The

[5] This literature mainly stems from the works of Coase (1937, 1960). It has two main branches (see the text).

[6] Yet, as Putterman (1984) argues we know no real world example of worker-run firms which makes the monitor residual claimant. The argument is empirically weak.

centrality of saving on monitoring cost in turn determines the ownership structure of the firm. Ownership goes to difficult-to-monitor assets to save on costs associated to them. Moreover, there is no authority relation in the firm, since neither the employer nor the employee is bounded by any contractual obligation to continue their relation (Alchian and Demsetz 1972, 777).

The transaction costs approach, i.e. the second branch of new institutionalism, stresses the role of *asset specifity*. This approach mainly derives from the works of Oliver Williamson (1975, 1985). Indeed, Williamson (1985, 86-89) argues that technology is not determinative since if alternative means of contracting can be described, the same technology can feasibly be employed by these alternatives. In his approach, the effect of technology is rather indirect through its effect on determining the most transaction cost economizing organization structure (Pagano 1992).

According to Williamson, transaction cost economizing matters, since all complex contracts are unavoidably incomplete, i.e. the legal system is not functioning perfectly. This is so mainly due to *bounded rationality* (see the previous section), and *opportunism*.[7] Market relations fail to support transactions of unique and imperfectly standardized goods, in which continuity of relations is important. In cases of such *asset specific* investments, contracts and governance structures are designed in such a way that they economize on bounded rationality and safeguard against opportunism (Williamson 1985).[8]

By the same token, the rationale behind the existence of the firm lies in its transaction costs economizing role. The threat of quasi rent appropriation would prevent specific investment in the absence of safeguards to which vertical integration, i.e. the firm, is the solution. In this regard, Williamson (1985, 249) argues that employment contract allows internal organization to adapt more effectively to changing market and technological conditions compared to

[7] Williamson (1985, 30) defines it as 'self-interest seeking with guile.'

[8] Some authors argue that Simon's concept of satisfying is absent in Williamson, and replaced by economizing on bounded rationality (Hodgson 1993, Loasby 1999, Pagano 2000).

commercial contracts in which procurement of the same good or service from autonomous suppliers requires mutual consent. The latter lacks command and control which is the decisive element of the employment contract (see below).

In the transaction costs approach, the firm with its internal hierarchy is the result of the cost economizing nature of contractual agreements in cases of asset specific investments; and in the property rights approach, it is the result of monitoring difficulties in production. Indeed, as Pagano (1993, 87) argues, the difference between these schools is more of a matter of terminology: 'Property rights, if interpreted in a general way, imply management rights and governance systems, and the latter are founded on explicit or implicit systems of rights.'

4. Inverted Schema: The Role of Property Rights and Power Relations

There is technological potentiality not determination. What is chosen among feasible technological alternatives, and in what directions technology develops are also a matter of power and property relations. This is tantamount to saying that technological change does not occur in an institutional vacuum. Incumbent institutions shape the evolution of technology, hence may affect the characteristics of assets employed in the production process.[9]

It is true that there is an unpredictable factor in scientific and technological progress, e.g. what Veblen (1899) calls *idle curiosity* as a driving force behind inventions and innovations. Even though imagination and curiosity play a role in

[9] Note that in the standard theory with zero transaction costs (no bounded rationality), perfect competition brings about the same efficient allocation of resources independently of the initial distribution of property rights (Pagano 2007, 69). In this economy, as Coase (1960) demonstrated, individuals will exchange their rights such that the final allocation of property rights will be efficient. The techniques and organization will be optimal independent of the initial distribution of property rights. In such a world who owns the firm and who hires whom are irrelevant since they will be efficiently determined by the competitive system. Alternative organizational forms acting in a competitive economy wouldn't change the results since, at equilibrium, organization of production would be such that the marginal productivity of each factor is maximized (Pagano 2007, 69-70).

technological change, too much emphasis on these factors may unduly favour explanations based on ‘hero inventors’ (Basalla 1988). On the contrary, the bulk of technological knowledge is created by intentional interventions of public (spending on military, education, healthcare etc.) and private actors.

Property rights determine the relationships of possession and coercion among economic agents. As Brenner (1986) put it, since property relations determine the economic actors’ rule for best strategy, they affect agents’ incentives for innovation, and thus provide a general pattern of development of productive forces. Incumbent power relations and property rights shape the technology used by the modern firm. Technological change is not an outcome of a socially unbiased advance of knowledge. It responds to the interests of the owners of productive forces. Therefore, certain technologies may be rejected when they threaten the existing authority relations in the modern workplace (Bowles and Gintis 1976).

In his seminal work, Marglin (1974) explores whether hierarchy and alienated work in the factory, i.e. capitalist firm, are indispensible for industrial development, or they are the result of existing social relations. He argues that the main function of the factory system is to transfer the decision making autonomy of workers on how much and how intensely work to capitalist (Marglin 1974). Moreover, scientific management assures direct control over the work through the control over the decisions that are made in the course of work: F. W. Taylor’s second principle, which states that all the possible brainwork should be removed from the shop floor and concentrated in the planning department (Braverman 1974).

Scientific management, as such, has had profound effects on the production process. Detailed division of craft cheapens its individual parts; thereby converts labour into automata performing very small and repeated tasks: ‘Babbage’s great principle of economical production’ (Braverman 1974, 80). This process, in turn, allows the extraction of useful knowledge from the shop floor, and concentrates it in the hands of managers. As Edwards (1979, 100)

puts it: ‘unless management knew in detail how production occurred, precise direction of worker tasks was impossible’.

The separation of conception and execution in the production process completes the conversion of labour into a general purpose asset. The most institutionalized and sophisticated form of control is what Edwards calls *bureaucratic control*. It makes power appear to emanate from the formal organization itself. Rule of law replaces rule by manager and supervisor command. Overall, there is nothing intrinsic in labour that makes it a general purpose asset. Historically, it has been due to the deliberate efforts of capitalists (Braverman 1974). Therefore, they reverse the argument which is developed by the new institutionalist approach.

5. Institutional Complementarities and Organizational Forms

Another possibility is that, as originally put by Pagano (1992, 1993) and Pagano and Rowthorn (1994), incumbent property rights could be the reason behind the adaptation of particular technology, and the characteristics of resources employed in production may be the reason behind the formation of certain system of rights. In other words, technology and property rights constitute organizational/technological equilibria in which they are optimal relative to each other: Property rights reproduce themselves via technology and technology reproduces itself via property rights.

We argue that such a framework requires two assumptions. First, agents are boundedly rational, in the sense that they have limited knowledge concerning the system. Second, there are different domains of choice, in which boundedly rational agents are not able to coordinate their choices across these domains. Importantly, it may not only be that agents are unable to coordinate their choices but also that they have conflicting interests. We argue that the second assumption is crucial, since transformation of production organization usually entails simultaneous changes in several domains.

In essence, it is the notion of institutional complementarities that constitute the foundations of an approach upon which different institutional arrangements of production could be built. Such institutional complementarities may prevent the emergence of alternative organizational forms, since the existence of complementarities implies that institutional arrangements across different domains constitute a coherent whole in which individual institutions may not easily be altered in isolation (see Milgrom and Roberts 1990a,b; Aoki 2001, 225-229).

In order to formalize such an argument, consider a population of i (employers) and j (employees) agents who are paired randomly for a single interaction. Assume that they produce a good, where property rights to the two parties are determined by i agents, whereas preference on how to produce, call it behavioural type, is chosen by j agents. For simplicity, assume that employers may offer one of the two rights: Under P, workers receive no rights and safeguards in the firm; while under R, employees have rights and safeguards in the firm such that they are willing to use their labour capacity, e.g. investing in skills. Rights and safeguards may be in the form of workplace autonomy, employment guarantees, or better work conditions.

Employees are also of two types. B type employees interpret R-rights as a sign of trust, hence reciprocate by using their labour capacity in the production process. On the other hand, when offered P type rights, they may feel distrusted, and retaliate by hiding their labour capacity. A type employees, on the other hand, irrespective of the rights offered, hide their labour capacity. In essence, we assume that non-verifiable aspects of work, such as reciprocity and work ethic in relation to the rights, are important to production (see, for example, Bowles and Belloc 2010 for such a framework).

Assume that payoffs for different types of interactions are as follows: $\pi_A^P \geq \pi_A^R$, $\pi_B^R \geq \pi_B^P$, $\pi_P^A \geq \pi_P^B$, and $\pi_R^B \geq \pi_R^A$ (see the table below). Hence, there are multiple equilibria. In this schema, we have two distinct property rights regimes, and four

techniques of production. Hence, we define technology by different combinations of property rights regime and behavioural types.

j agents / i agents	**Behavioral type A**	**Behavioral type B**
Property rights P	π_A^P, π_P^A	π_B^P, π_P^B
Property rights R	π_A^R, π_R^A	π_B^R, π_R^B

Writing the fraction of j agents who are type A as τ, the expected payoffs to i agents offering the P and R contracts are:

$$V_P = \tau\pi_A^P + (1-\tau)\pi_B^P$$

$$V_R = \tau\pi_A^R + (1-\tau)\pi_B^R$$

Similarly, writing the fraction of the i agents offering property rights regime P as φ, the expected payoffs to the A and B behavioural types are:

$$V_A = \varphi\pi_P^A + (1-\varphi)\pi_R^A$$

$$V_B = \varphi\pi_P^B + (1-\varphi)\pi_R^B$$

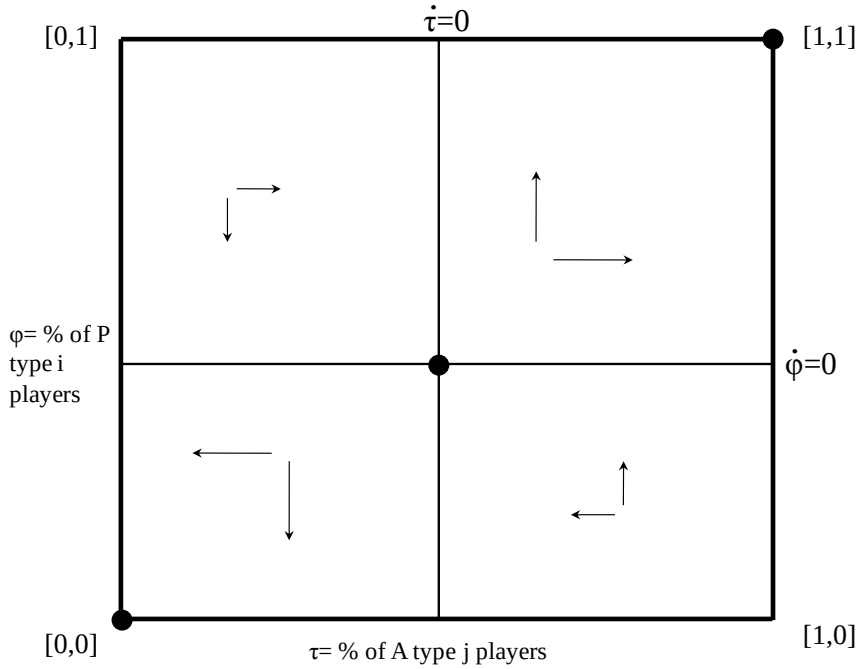
What types of rights and behaviours would we expect to observe in this population? Secondly, how could we characterize a transition from one regime to another? To answer the first question, consider the space defined by all

possible combinations of rights and behavioural strategies, i.e. $\varphi \in [0,1]$, and $\tau \in [0,1]$. Then, explore the changes in both φ and τ over time. In order to do that, assume that both groups of agents periodically update their strategies by switching to strategies with higher payoffs. This process gives us the following replicator equations (Bowles 2006).

$$\dot{\varphi} = \varphi(1-\varphi)(V_P - V_R)$$

$$\dot{\tau} = \tau(1-\tau)(V_A - V_B)$$

The stationary values of φ and τ in this dynamic system are $\dot{\varphi} = 0$ for $\varphi = 0$, $\varphi = 1$, and $\dot{\varphi} = \varphi^*$, and $\dot{\tau} = 0$ for $\tau = 0$, $\tau = 1$, and $\dot{\tau} = r^*$. The resulting dynamical system is illustrated in the figure below. The point $(\varphi^*, \dot{\tau})$ is stationary, but is a saddle. Thereby, small movements away from the point are not self-correcting. The asymptotically stable states are $(\varphi, \tau) = (0,0)$ and $(\varphi, \tau) = (1,1)$. Which state occurs is determined by the initial conditions.



We see that two outcomes are likely to occur, namely high frequency of both P rights and A behavioural type, or the opposite case with R rights and B behavioural type. In order to answer the second question, let us convert the above dynamical system into an ergodic process. We could do so by introducing the possibility of intentional idiosyncratic play. Assume that in every period there is a probability $\partial \in (0,1)$ that each agent takes intentional non-best response. This process transforms our dynamical system into an ergodic process (Young 1998, Bowles 2006).

Particularly, when none of the equilibrium is Pareto superior, e.g. payoffs specified above is such an example, depending on the basin of attraction of the system, fraction of i and j agents playing idiosyncratically will have an incentive to non-best respond, because by so doing they may induce their best responding partners to change their strategy in the following periods. Yet, the introduction of idiosyncratic play does not mean that all states are equally likely, since it requires a large amount of such play to change equilibrium. Therefore, changes in individual behaviour could not amount to explain a shift in equilibrium.

An exogenous shock to the system, which could affect the basins of attraction of different systems, may lead to change. For example, Pagano (1993, 110-112) argues that the system of production in Germany and Japan with several safeguards, at the industry and firm level respectively, is due to such a shock. He claims that in the US workers were employed without any safeguards and rights (P-A equilibrium), hence they invested very little in skills. On the other hand, German and Japanese systems of production with skilled workers (R-B equilibrium), in part, is due to a strong property rights shock that came after both countries lost the Second World War. In both countries, employers were punished for their war effort.

If institutional complementarities exist, different institutional arrangements may not be even Pareto comparable. Hence, the existence and persistence of (even inefficient) organizational equilibrium under competition are possible contrary to

the well-known claims that are found in the literature, e.g. Alchian (1950). Property rights and technology at any given time have more or less a character of organic whole so that any change in one domain of the system involves a change at other domains. Incumbent set of institutions can be seen as a set of mutually supporting rocks that have come about in a process of cumulative growth (Pagano 2000).

Competition may lead to the selection of the best among similar organizational forms, yet at the same time, may prevent the development of new (potentially more efficient) forms due to the inferiority of the hybrids (Pagano 1993, 134-135). The role of power relations, hence incumbent property rights regime, is paramount since those who benefit from the incumbent arrangements may be endowed with resources and competence to perpetuate them. Overall, efficiency driven stories are not tenable in determining technology-rights equilibria (Pagano 2001). Overall, efficient change in economic organization is difficult to describe, if social and economic systems are characterized by such institutional complementarities.[10]

6. Multiplicity of Organizational Forms: Some Implications

At the dawn of the 20th century the concentration of former artisans and domestic workers under one roof, i.e. the factory, away from home was almost completed. The de-skilling of workers, mechanization of production, and the supervision of it by professional managers were the main characteristics of this new mode of production. Since then, modern business enterprise, i.e. capitalist

[10] Besides, the existence of such complementarities implies that institutional evolution may have a *punctuated* character (see Eldredge and Gould 1972). Namely, there is no slow and steady transformation from one technological system to another. Continuous change in existing technology is part of a technological trajectory confined to a particular technological paradigm, whereas discontinuous and sharp changes are associated with the birth of new paradigms. As Mokyr (1990) pointed out, historically, we do not observe gradual evolution in technology, but long periods of stagnation punctuated by sudden outburst like the industrial revolution. The literature on technological paradigms (Dosi 1982) and techno-economic paradigms (Perez 1985), in which different technological trajectories are generated by alternative property rights regimes examine this fact (Pagano 1993, 90).

firm has been an important complement to the market in coordinating economic activities and allocating resources (Chandler 1977, 1990). Claims on the efficiency of the capitalist firm rely on this historical background. We now provide a broader perspective on different institutional arrangements that have been observed in the last two centuries.

It is foremost the institution of employment contract that demarcates the *capitalist firm* from other organizational forms. Not all firms are capitalist. The defining characteristic of a capitalist firm, the dominant organizational form of the last two centuries, is the existence of employment contract that regulates the relation between employer and employee. Employment relation is one of the fundamental characteristics of modern societies, which we live in (Simon 1979).

It is different from commodity exchange and hence sales contract, since employee does not offer a specific service, but an undifferentiated time and effort (Simon 1951).[11] It assigns employer the right of decision making power over the use of employee. As Coase (1937) pointed out, when a worker moves from one department to the other he does not go because of a change in relative prices but simply because he is ordered to do so. Importantly, employment relation entails *authority* in the sense that whenever a person is subject to it, his choices are excluded from playing a role in the regulation of his actions, and are replaced by the choice of the authority (Archer 1996). Bowles and Gintis (1996a) argue that the standard argument for democratic governance in politics, i.e. it is a defense against the abuse of otherwise unaccountable power, applies to the employment relation as well.

An alternative institutional arrangement that has kept the attention of researchers as well as practitioners is *self-management* (self-managed firms or workers' control in the production process). It is different from the former because of the fact that decisions are made by workers themselves. The decision making power is distributed and profit is shared among workers. In self-managed firms, workers determine output collectively using some

[11] See Hodgson (1999) and Screpanti (2001) for contemporary accounts of the issue.

democratic choice mechanism in which there is no ex ante wage determination (Dow 1993). The workers of the firm, in a politically egalitarian or democratic manner, have ultimate authority over the decisions of the enterprise, including the right to delegate some or all decisions to managerial organs. Note that this is different than egalitarianism in income distribution, or direct democracy in decision making. Hence, some degree of hierarchy and job specialization is not ruled out in self-management (Putterman 1984). In other words, workers may appoint managers, but they have effective monitoring power over them (Screpanti 2010).[12]

In both (pure) forms, the firm does not have to belong to the insiders. What really matters to demarcate a capitalist firm from a self-managed firm is the type of contract that regulates the relations inside the firm, not the ownership of assets. Therefore, there may be private or public property rights in productive assets.[13] Alternative institutional arrangements, foremost, are about the method of coordination of the division of labour within production units, which leaves open the question of the method of coordinating the relations between production units as well as the question of property rights (Putterman 1990).

The systems of production in Germany and Japan (see the previous section) stand in the middle of the above defined (pure) forms. Even though employment contract regulates the relations between the employer and the employee, the latter is given rights and safeguards compared to the standard employment relation, i.e. classical capitalist firm. In Japan individual firms developed several safeguards, hence workers invested quite a lot in their (firm specific) skills. This happened in Germany at the industrial level with well developed occupational

[12] In self-managed firms residual claimancy may induce greater effort from partners (Bowles and Gintis 1993, 1996b). Moreover, peer-to-peer monitoring may mitigate the monitoring problem (Screpanti 2010).

[13] Economic systems could also be categorized according to asset ownership, i.e. private or public ownership of (mainly) physical assets. Yet, As Screpanti (2010) argues, there is no a priori reason to believe that authority derives from the residual right of control on wealth. There is nothing about private asset ownership that implies routine control over the ways in which assets are used. In theory, workers can lease physical assets from their owners without losing control over the production process (Dow 2003).

markets and vocational training. In essence, both types correspond to giving power and rights to workers compared to classical capitalism (or Taylorism) with no rights to workers (see also Pagano 2007, 69-70).

All these alternative organizational forms represent different ways of knowledge collection, transformation and utilization based on available technology and property rights. Importantly, social systems involve dominant structures, what Hodgson (1988) calls ‘principle of dominance’. The characteristics of the system may be defined by giving reference to these dominant structures. What we have done for the employment contract is a case in point. Still, non-dominant elements are necessary parts of any system, i.e. ‘principle of impurity’. No system exists in its pure form. There is institutional plurality (see Hodgson 1988 for the details of the argument). In capitalism alternative organizational forms such as workers’ control as well as hybrid forms such as German and Japanese types of production co-exist with the dominant form.

What explains the dominance of employment contract in modern economies? In capitalism, labour cannot be bought and sold. This is the restriction imposed by the incumbent property rights regime. On the other hand, the treatment of the rental of labour is not substantially different from the rental of other resources in the theory. Yet, this type of analysis depends on costless definition, enforcement and transfer of private property rights. When they are costly, initial distribution of rights matters (see the formal model above). Moreover, in a world of positive transaction costs, labour cannot be treated in the same way as other non-human resources, i.e. there is no perfect symmetry between labour and capital. This asymmetry constitutes two interrelated yet distinct social conflicts: One is on the distribution of the product, and another is on the organization of the workplace.

First, capital can be pooled, whereas labour cannot. In a corporation no individual investor owns an identifiable piece of the firm’s physical assets; in other words each capital supplier is not free to withdraw his or her personal machine. Hence, bargaining problem among the capitalists can be solved by

not allowing each capitalist to own specific machine but to accept shares in the firm. This is a feasible solution since capital is intrinsically *mobile*, i.e. it can be separated from the capitalist. Hence, capital owners can create a cartel that bargains as a unit against workers (Leijenhufvud 1986, 219).

On the other hand, labour cannot be separated from the worker; therefore, workers cannot pool their labour power. A symmetrical solution would require a worker to sell his own person into slavery in return with an equity share in the firm (Leijonhufvud 1995, 73). In the absence of slavery, there would be a disincentive to collective investment, especially if workers had the alternative of paying themselves higher current incomes, i.e. the so-called long horizon investment problem stemming from the non-separability of labour from the worker. This is known as the problem of *alienability* (Dow and Putterman 2000, Dow 2003). It is risky for workers to make undiversified investment to their own firm. Hence, wealth inequality constraint – the riskiness of concentrating wealth in a single asset may be an important reason behind the rarity of self-managed firms (Bowles and Gintis 1996b).

Second, workers cannot be indifferent to the allocation of labour time since it is the allocation of themselves (Pagano 2007, 71). Lack of liberty in labour allocation may lead to alienated labour, and underinvestment in skills. Thereby, de-skilling of workers may decrease worker welfare even if it increases profits of the firm.[14] We capture this fact, formally, in our model by different responses of workers to alternative property rights regimes. In the Marxist literature, for example, labour force is not regarded as a mere factor of production but as a self-conscious class actively opposing and obstructing the extraction of surplus value from it (Elster 1983). Worker does not surrender his capacity to work to capitalist. What worker sells is not a pre-agreed amount of labour but the power

[14] According to Pagano (1985), in neoclassical theory workers only have preferences over their consumption decisions. Therefore, the wealth of labor is only affected via consumption. Interestingly, another implication of taking workers' preferences into account may be another reason behind the rarity of self-managed firms. Capitalists are only interested in the maximization of profits; workers may have diversified wants related to the workplace. This may lead to higher costs in reaching an agreement in worker controlled firms, i.e. collective action problem (Hansmann 1996).

to labour over an agreed period of time. In return, the capitalist buys only the potential to do something. The actual outcome depends on non-verifiable aspects of work, e.g. work ethic, as well as managerial capacity. Thereby, workers, in pursuit of autonomy and better work conditions, hide their labour capacities, and employers try to overcome worker resistance by way of monitoring, incentive pay schemas etc. This is why workplace is a *contested terrain* (Bowles and Gintis 1993, Screpanti 2001).

Trade unions assume two roles in these interrelated yet distinct conflicts. First, they bargain on the method of production. Namely, they codify work rules to avoid restrictive labour withholding practices, and transform these benefits from informal methods of self-protection to contractual agreements. Therefore, unions are check on managerial discretion. Second, trade unions are workers' best strategy in the struggle for sharing joint surplus created in the firm (Leijonhufvud 1986, 220).

7. Conclusion

Technological knowledge is central to every economic activity. Yet, technological change does not occur in an institutional vacuum. To put it in another way, technological change only sets the limiting conditions of what is possible. Power relations and property rights play an important role in the evolution of technology, since those who control the resources are able to choose from the available technologies the one most favourable for their interest. By focusing on the interplay between these two forces, we are able to abandon the notion of production as a natural process, and place it into a framework where the organization of production is seen as a social phenomenon.

As we have seen, the interplay between technology and property rights and the existence of complementarities imply that institutional arrangements across different domains are a coherent whole in which individual domains, e.g. rights

or technology, may not easily be altered in isolation. In such an environment the existence and persistence of inefficient organizational equilibrium under competition is possible. In essence, in order to explain the existence of a structure it is neither necessary nor sufficient to show that it is efficient (Hodgson 1996).

Certain institutional arrangements, i.e. capitalist firm, may seem to be the best practice under certain institutional setup, not because other forms are eliminated via competition, but because competition and selection take place with regard to an institutional setup shaped by the incumbent power relations and property rights (Hodgson 1988). Moreover, the same institutional setup may allow incumbent property rights to reproduce themselves and block the proliferation of alternative property rights regimes and associated technologies. In other words, organizational evolution does not necessarily lead to perfection (Hodgson 1996). Hence, it should be depicted not as a linear path leading to perfection, but rather as a branching tree.

Once we quit the technologically determinist explanation, and acknowledge the asymmetry between the so-called factors of production, i.e. capital and labour, we can better identify the social and historical dimension of the production organization. By doing so, for example, we can see the fictitious nature of labour as a commodity (Polanyi 1944). Subsequently, it may help us to better evaluate the problems related to this fictitious commodity, and may open the way to consider workplace democracy and collective bargaining on the side of labour without being trapped by efficiency considerations.

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CHAPTER 2

ORGANIZATIONAL FORMS IN THE KNOWLEDGE ECONOMY: A COMPARATIVE INSTITUTIONAL ANALYSIS

Abstract

This paper attempts to provide an analytical framework to analyze organizational forms in the knowledge economy. We first outline some historical trends that have transformed the organization of production over the last few decades. We show that this transformation has taken place not only in the realm of intellectual property rights (IPRs) regime, but also in technology. Finally, by recourse to a formal model, we study the determinants of the distribution of alternative institutional arrangements in this new environment. We argue that organizational ecology is mainly determined by knowledge network effects, and complementarities between IPRs and technology.

JEL Codes: K11, L23, O34

Keywords: Organizational forms, technology, IPRs, institutional complementarities

1. Introduction

Describing our economies as knowledge-based or knowledge-intensive is now commonplace. In this context, researchers try to make sense of technological developments, which have taken place in mainly advanced economies over the last few decades. As a matter of fact, any kind of production is knowledge-based. Knowledge economy corresponds to a case in which these issues are of

utmost importance; that is, to a dramatic increase in the importance of knowledge as a means of controlling production.[15]

Yet, we argue that, even though technology has an effect on the nature of production organization, alone it does not determine it. The degree of viability of any work organization is influenced by the property rights regime, and vice versa. If both ways of causality exist, initial distribution of both property rights and work relations may exert an enduring influence on the evolution of the system.[16] In this paper, we contribute to the literature by providing a theoretical framework that clarifies how production organization and intellectual property rights (IPRs) regime co-evolve in the knowledge economy.

The structure of the paper is as follows: In Section 2, we outline some historical developments that have transformed the organization of production over the last few decades. Then, by recourse to a formal model, we study the determinants of the distribution of alternative institutional arrangements in the knowledge economy (Section 3). Section 4 addresses some implications.

2. Historical Trends

2.1. The changing nature of technology

Production organization over the last two centuries, i.e. since the industrial revolution, has witnessed the gradual replacement of home production and small-scale industries by factory production. The rise of the factory system has been accompanied by the diffusion of employment relation as the dominant

[15] Many researchers have documented the increased value of intellectual property relative to the value of physical property in business firms (for example, see Idris 2004, Corrado et al. 2006).

[16] See Pagano (1993), and Pagano and Rowthorn (1994) on the co-determination of technology and property rights. Elkin-Koren and Salzberger (2004) have a similar argument in the context of the knowledge economy.

form of work organization. It is one of the fundamental characteristics of modern societies, which we live in (Simon 1979).[17]

Technological developments over the last three decades have the potential to undermine this seemingly linear trend. The essence of these developments is that whereas previous technological paradigms were characterized by high energy and material intensity, there has been a recent trend towards the rise of knowledge intensity in production. Economy has become less machine intensive, and more knowledge intensive. In other words, there has been a shift from resource-based economy to knowledge-based economy. This shift is foremost due to the microprocessors and internet, and related changes they have ushered in since the 1970s. Setting aside different connotations on what has happened,[18] the essence of this transformation is the role attributed to the developments in information and communication technology (ICT).

Increase in the knowledge content of work has concretized tacit and dispersed character of knowledge, i.e. idiosyncratic (difficult-to-monitor) knowledge in the hands of workers (Zuboff 1989). The nature and dispersion of knowledge are such that there are difficulties in dealing with this tacit and idiosyncratic knowledge on the side of production managers. As knowledge embodied in workers becomes relatively more important, the central legitimation for managerial authority is eroded, since managerial authority, foremost, is based on the discipline and supervision of workers that is made possible by the separation of conception and execution on the shop floor. It entails transferring useful knowledge on the shop floor to the managerial authority (Braverman 1974, Edwards 1979).

Managerial control is about the distribution and control of knowledge in the organization. If production is under managerial control, whereas valuable information is in the hands of workers; it is not only difficult to supervise and

[17] Seminal papers on the issue are Coase (1937) and Simon (1951).

[18] Perez (1985) calls it information and communication technology (ICT) paradigm. See also Dosi (1982) on technological and techno-economic paradigms. According to Piore and Sabel (1984), it is the crisis of mass production.

monitor these skilled workers, but it is also difficult to motivate them. The latter arises simply because obedience can be dysfunctional when tasks require intellectual skills, since direct supervision or observation cannot discern the quality of performance. Moreover, if the productivity of a worker is bounded with her intellectual skills, it can be mainly enhanced with further learning. Yet, learning requires a learning environment where dialogue is encouraged. Employers and workers can hardly be partners if there is one way mirror between them (Zuboff 1989).

Knowledge intensive technology, as such, has the power to free human beings for a more comprehensive and abstract learning where work requires intellectual skills and collaboration with flattened hierarchical structures.[19] Hence, there is an increasing inefficiency in classical employment relation, since the new technology challenges the distinction between manual and mental work as it has evolved in the last two centuries. Consequently, work organization may require a new division of knowledge as well as rights that can support intellectual activity.

These developments signal the inversion of the relation between labour and capital: Whereas labour has become difficult-to-monitor asset, capital has gradually become general purpose. The latter is mainly due to the developments in the ICT. Software allows redesigning machines or tools by simply migrating software packages from one machine to the other by reprogramming. Numerically controlled machinery becomes general purpose (Piore and Sabel 1984). Pagano (2008) argues that, in order to improve efficiency, workers should be given strong incentives in the production process, since the exploitation of this new technology requires numerous individuals to

[19] As Boulding (1966, 30) put it, there are *diminishing returns to hierarchy* in knowledge production.

accumulate idiosyncratic knowledge related to their skills (see also Pagano and Rossi 2011).[20]

The second wave of technological changes dates back to the 1990s. With the advent of internet, networks and variety of software applications started to be used not only in business applications, but also by individuals at home. It has created an industry where physical capital plays a negligible role, e.g. software industry. In particular, low cost and high efficiency of communication among human participants have created an industry with personal computers used by individuals connected via internet, i.e. what Benkler (2006) calls *networked information economy.* It has created an environment in which agents interact without any need of physical proximity, e.g. *commons based peer production* (see below). In essence, cheap and efficient transmission of knowledge permits the coordination of widely distributed agents, and the aggregation of their efforts into products.

2.2. The new IPRs regime

Even though substantial in its nature, developments in the last few decades have not been confined to the technology. The unprecedented developments in the IPRs regime have been one of the most important factors in the transformation of the world economy in the same period (Coriat and Weinstein 2011). Permanent increase in the economic importance of knowledge, at the same time, has brought an overreaching enclosure movement on it.[21] On the other hand, researchers have always been critical to the institution of private property on knowledge. The modern argument, since at least the seminal works

[20] In the new institutionalist approach, monitoring and specificity characteristics of assets *efficiently* determine rights associated with these assets. See Alchian and Demsetz (1972), and Williamson (1985).

[21] In this regard, knowledge can be added as the 4th fictitious commodity into Karl Polanyi's (1944) framework. The commodification of knowledge assumes many forms, that is, intellectual property is used to describe several legal regimes, e.g. copyright, trade secrets and patents (see Besen and Raskind 1991).

of Nelson (1959) and Arrow (1962), stresses the public good (non-excludable and non-rival) nature of information.[22]

The aim of any IPRs regime is to favour inventive activity. Initially, in the 19th century, the system aimed at favouring individual inventive activity. Therefore, firms were not able to receive patents directly for inventions developed during the production process. Yet, triggered by the developments in the US, patent regimes all around the world have evolved in such a direction that granted exclusive control rights to corporations over the knowledge produced within organizations (Coriat and Weinstein 2011, 3-4). This legal transformation, i.e. the recognition of employer control over the firm specific intellectual assets, took place steadily between 1830 and 1930 (Fisk 1998). It was mainly due to the rise of the business corporation (Schumpeter 1954 [1942]), and the recognition of employer's rights over employees' patents, in which companies became able to acquire an exclusive control over their employees' inventions (Coriat and Weinstein 2011, 7).[23] Since then, the existence as well as the content of IPRs regime have been a battle ground for interest groups all around the world.[24]

There have been important amendments to the IPRs regimes in the last few decades. They were triggered, once again, by the developments in the US (Coriat and Orsi 2002). Patentable subjects have been expanded to new areas such as software, business methods, and living entities. The Patent and Trademark Amendments Act – well known as Bayh-Dole Act (1980) - in the US allowed public research institutions to patent their findings. It was followed by the introduction of technology transfer offices in universities that grant patents to

[22] Non-rivalry allows easy exploitation of existing knowledge stock by users (static efficiency). However, if everybody could use it, nobody would be willing to produce it (dynamic inefficiency). Private intellectual property makes information appropriable commodity, and precisely to the extent this policy is successful, there is under utilization of existing information stock (Arrow 1962). As Demsetz (1969) pointed out, there is a difficult to achieve balance in information production and distribution.

[23] This is the *shop right* doctrine, which gives the employer the right to use an employee's invention without paying him royalties. Hence, employment contract by which the company controls the activity of the worker includes appropriating the results of that activity (Merges 1999: Coriat and Weinstein 2011, 9).

[24] Salzberger (2011), Lessig (2004), Chang (2001, 2002). See Machlup and Penrose (1950) for a classical treatment of the issue.

basic knowledge (Orsi and Coriat 2006). Moreover, in 1982 the courts of appeal in the US shifted from copyright regime to patent regime for computer software.[25]

Innovation is a cumulative process. New knowledge is created by different combinations of already existing knowledge; what Scotchmer (1991) calls *standing on the shoulders of the giants*. By increasing the cost of new discoveries, intellectual property can lower the rate of subsequent innovations. In addition to this, private property on ideas creates *global excludability* as opposed to private property on tangible assets. In other words, IPRs create rights for an individual or a firm that involve duties for the rest of the people around the world (Pagano 2007).[26]

The result of all these changes is that patent regimes are used as an industrial strategy to create barriers for newcomers, since initial concentration of patents in the hands of few firms leads to the creation of practical monopolies. Protection that is afforded by existing intellectual property, in turn, is strategically used to achieve private advantage at the expense of general innovative progress. Hence, money and resources are spent on rent-seeking and bribery rather than innovation.[27]

Inventions and innovations are the fruits of growing knowledge stock of society, rather than being an outcome of the efforts of isolated inventors. This manifests itself in the fact that, many times, several people come up with the same invention simultaneously.[28] Several studies document that the patent system did

[25] These developments have also raised doubts on the extent and quality of patents and the working of the patent offices (Jaffe and Lerner 2004).

[26] As Boldrin and Levine (2008, 171) argue, information is not like any other commodity traded in markets, since owning an abstract idea means that you have the right to control all copies of that idea.

[27] Von Hippel (2005), and Boldrin and Levine (2008) show how large inventory of patents can create grounds for patent infringement suits, and how such threats can discourage others from investing in innovative activities. These developments echo Veblen's (1904) concerns about the conflicting objectives of businessmen and engineers in modern societies.

[28] See, among many, Basalla (1988), and Boldrin and Levine (2008) for historical accounts of this phenomenon.

not play a crucial role even in major technological shifts such as the industrial revolution (Mokyr 2009). Many technological developments in the last century took place without any patent protection, e.g. software industry. It is also true that large productivity increases occurred in agriculture without substantial patent protection in the last century (Boldrin and Levine 2008, Gilbert 2011).

3. Organizational Forms in the Knowledge Economy

3.1. The model: General setting and assumptions

In this section, we develop a formal model, which allows us to discuss the developments outlined in the previous section in a single framework. Assume that our economy is populated by two groups: i and j agents. The first group (i agents) has control rights over the knowledge stock of society; thereby has decision-making power over alternative IPRs regimes. i agents choose between two rights: Copyleft (superscript L) or copyright (superscript R). The first corresponds to a non-proprietary strategy, i.e. *disclosure-prize driven system;* whereas the second corresponds to a proprietary one, i.e. *private intellectual property* (Pagano 2008). In the former, the aim is to share knowledge with public; whereas the latter privately appropriates useful knowledge. Therefore, the community of i agents playing L is concerned with additions to the stock of public knowledge, while the community of i agents playing R is concerned with adding to the stream of rents that may be derived from possession of private knowledge.

Production takes place when each i agent interacts with an agent from the second group (j agents). j agents are workers who provide the human input. They enter into work relation with i agents. We assume two types of workers: Partners (superscript P) are those who have preferences over the form of the rights under which they work. In other words, they may be reciprocal to incentives stemming from alternative IPRs regimes, whereas some workers (superscript E) may be irresponsive to such incentives. This assumption

captures the fact that control over the knowledge base of the firm is the ultimate reason behind the managerial control over the production process. If some employees, i.e. partners, are sensitive to such incentives, when matched with i agents playing R, there will be a tendency towards underinvestment in the related skills on the side of non-owner partners, since they will be vulnerable to the possibility of loss of value of their investment specific to intellectual property. It is because a worker who has acquired skills specific to that piece of intellectual property is denied to access to it under private intellectual property rights regime (Pagano and Rossi 2011). From the above formalization, we can see that, when owners select a private property rights scheme they reveal alternative preferences over embodied (workers') knowledge or disembodied private knowledge.

Overall, production is governed by i agents' choice over the IPRs regime, and j agents' choice over the type of work relation. In this setting, *initial* allocation of property rights over intellectual assets may exert an enduring influence on the evolution of work relations simply because pre-existing distribution of ownership and control rights in the hands of few owners may inhibit the accumulation of embodied intellectual skills on the side of the non-owners. Alternatively, when the IPRs are already dispersed among many agents, the disincentive effect of the exclusion of disembodied knowledge is negligible; hence non-owners can accumulate embodied intellectual skills (Earle et al. 2006). Moreover, these two cases may reinforce each other; hence, they bring about multiple equilibria.[29]

Formally, i agents' payoff is a function of individual benefit (depending on the type of j agent they are matched with), and *network effect*. What the latter means is that individual payoffs are affected by the amount of people playing that strategy.

[29] Simplification of this sort may seem limiting, since we ignore the complexity of organizational forms. In reality, we have a continuum of institutional arrangements as well as hybrid forms. Yet, our aim is not to provide a complete list of organizational forms in the knowledge economy. This way of stylized exposition enables us to focus on pure forms, in which the interplay between IPRs and workers' types can be studied in a single framework.

Payoff functions for i agents playing L strategy are

$$\pi_{LP} = Q_L + a_1\varphi - w \qquad (1a)$$

$$\pi_{LE} = Q_R + a_1\varphi - w \qquad (1b)$$

where π_{LP} is the payoff when i agents are matched with j agents playing P, and π_{LE} is the payoff when i agents are matched with j agents playing E. φ is the fraction of i group playing L strategy. The parameter a_1 measures the network effect and represents marginal gains from an increase in φ. Q_L and Q_R are individual benefits when partners are matched with P playing and E playing j agents, respectively (see below). Finally, w is the cost of employing j agents (see Table 1 for the matrix of payoffs).

i agents / j agents	**R**	**L**
P	$w - \delta_R; Q_R + r + a_2\varphi - w$	$w + a_1\varphi - \delta_L; Q_L + a_1\varphi - w$
E	$w - \delta_E; Q_R + r + a_2\varphi - w$	$w - \delta_E; Q_R + a_1\varphi - w$

Table 1

Payoff functions for i agents playing R strategy are

$$\pi_{RP} = \pi_{RE} = Q_R + r + a_2\varphi - w \qquad (2)$$

where π_{RP} is the payoff when i agents are matched with j agents playing P, and π_{RE} is the payoff when i agents are matched with j agents playing E. r is the rent that is derived from the possession of private knowledge. Private intellectual property makes access to information resources costly for non-proprietary producers, while improving benefits only for proprietary models. It is so since private appropriators could rely on proprietary knowledge that they already have at their disposal in the production process, while non-proprietary producers lack this opportunity. In other words, the owners of intellectual property benefit from the exclusion of competition.[30]

L agent's decision makes knowledge a public good available to everybody, hence R agents indirectly benefit from this freely available knowledge. Yet, with less marginal gains, that is $a_1 \geq a_2$. This is due to the fact that not all public knowledge is available for private use, because non-proprietary producers put restrictions on the private appropriation of knowledge, i.e. public knowledge could be used as long as the distribution terms do not change. For example, free software is protected by General Public License, which guarantees unlimited copying, redistribution and modification of the software. Importantly, it includes a requirement that any derivative work that contains free software will be subject to the same license (Stallman 2002). Finally, we assume that $Q_L \geq Q_R$, since partners reciprocate when matched with i agents playing L strategy. When offered R type rights, P type j agents provide low effort. We also assume that, for the sake of simplicity, this individual payoff is equal to the one provided by E type j players.

j agents' payoff is a function of individual benefits (taking into account the cost of effort associated with different types of labour), and the network effect. L strategy, for j agents playing P, is interpreted as a signal for collective production and knowledge sharing, and hence partners reciprocate. In other words, there is a *complementarity* between the IPRs regime and work relation.

[30] Indeed, patents are effective appropriation mechanisms in some industries such as pharmaceuticals and biotechnology, while ineffective in some others such as software (Cohen, Nelson and Walsh 2000; Graham et al. 2009).

On the other hand, partners who are matched with i agents playing R are exposed to the risk of undervaluation of their investment, since control rights over the IPRs are retained by i agents. The presence of non-cooperation in the realm of IPRs thus constitutes a threat to the realization of investments in intellectual skills on the side of j agents playing P.

Payoff functions for j agents playing P strategy are

$$\pi_{PL} = w + a_1\varphi - \delta_L \qquad (3a)$$

$$\pi_{PR} = w - \delta_R \qquad (3b)$$

where π_{PL} is the payoff when j agents are matched with copylefters, and π_{PR} is the payoff when j agents are matched with copyrighters. The interpretation of a_1 is the same. Last terms in the equations represent the cost associated with each type of labour, where we assume that $\delta_L \geq \delta_R$. P type workers incur a higher cost of effort.

Payoff functions for j agents playing E strategy are

$$\pi_{EL} = \pi_{ER} = w - \delta_E \qquad (4)$$

where π_{EL} and π_{ER} are the payoffs when they are matched with i agents playing L strategy, and with i agents playing R strategy, respectively. j agents playing E strategy do not value *per se* control rights over intellectual assets. Hence, we assume that $\delta_R \geq \delta_E$, i.e. there is a subjective cost when partners are matched with R type i players.

3.2. Dynamics

We assume that institutions and preferences are acquired and abandoned by a trial and error process. In each time period, agents from one population are randomly paired with agents from the other population (each i agent is matched with one j agent). The process by which preferences acquired may take place

under the influence of family, schooling etc. (Bowles 2006). Hence, our agents do not condition updating their preferences on the kind of rights or relationships they are offered, rather they update by best responding to the distribution of them in the past. They evolve in a decentralized environment under the influence of payoff differences, therefore while both IPRs and workers' types choices are endogenous, neither of them is a result of instantaneous individual maximization.

To provide a framework for understanding the dynamics of the game we express the expected payoffs to i and j agents as a function of the distribution of relationship and rights types. The expected payoffs to i agents, when the fraction of j agents playing P is τ, are

$$\pi_L = \tau(Q_L + a_1\varphi - w) + (1-\tau)(Q_R + a_1\varphi - w) \qquad (5a)$$

$$\pi_R = \tau(Q_R + r + a_2\varphi - w) + (1-\tau)(Q_R + r + a_2\varphi - w) \qquad (5b)$$

Similarly, expected payoffs to j agents, when the fraction of i agents playing L is φ, are

$$\pi_P = \varphi(w + a_1\varphi - \delta_L) + (1-\varphi)(w - \delta_R) \qquad (6a)$$

$$\pi_E = \varphi(w - \delta_E) + (1-\varphi)(w - \delta_E) \qquad (6b)$$

As we have said, both types periodically update relational agreements and rights they offer by best responding to the distribution of play in the other group in the previous period. The updating process is such that at the beginning of each period i and j agents are exposed to a relationship and rights model randomly selected from their sub-population and updating occurs according to the payoff differences. This process gives replicator equations (Bowles 2006)

$$\dot{\varphi} = \varphi(1-\varphi)(\pi_L - \pi_R) \qquad (7a)$$

$$\dot{\tau} = \tau(1-\tau)(\pi_P - \pi_E) \qquad (7b)$$

Substituting the payoffs from the equations (5a)-(6b), the following dynamics results

$$\dot{\varphi} = \varphi(1-\varphi)[(a_1 - a_2)\varphi + l\tau - r] \qquad (7a')$$

$$\dot{\tau} = \tau(1-\tau)(a_1\varphi^2 - \delta_1\varphi - \delta_2) \qquad (7b')$$

where we define, $l = Q_L - Q_R$, $\delta_1 = \delta_L - \delta_R$, $\delta_2 = \delta_R - \delta_E$. We already know that $a_1, a_2, l, r, \delta_1, \delta_2 \geq 0$ (see section 3.1).

3.3. The analysis of equilibrium points

The point $(\varphi^*, \tau^*) = (0,0)$ is a stationary state. It is stable under the above assumptions (see Section 3.2). The point $(\varphi^*, \tau^*) = (1,1)$ is also a stationary state. It is stable when a_1 is sufficiently high. Formally, when $a_1 \geq \delta_1 + \delta_2$ and $a_1 - a_2 \geq r - l$. Indeed, the conditions that require stability of this point clarify also the conditions under which public and private models of knowledge appropriation compete. In particular, when we assume that $r \geq l$,[31] the latter condition assures that it is only private gains that are higher for the copyrighters. The former, on the other hand, says that returns to sharing knowledge are higher that the cost of effort for the employees.

When payoffs are equal, i.e. $\pi_L = \pi_R$ and $\pi_P = \pi_E$, we have an interior stationary state.[32] Qualitative analysis shows that the interior fixed point is a saddle (see Figure 1a below).[33] Indeed, the lines $\dot{\varphi} = 0$ and $\dot{\tau} = 0$ do not have to intersect. Yet, under that case it is still only the fixed points $(\varphi^*, \tau^*) = (0,0)$

[31] Namely, when individual returns are higher for the copyrighters due to the rents from knowledge privatisation.

[32] Formally, by solving the system $a_1\varphi^2 - \delta_1\varphi - \delta_2 = 0$

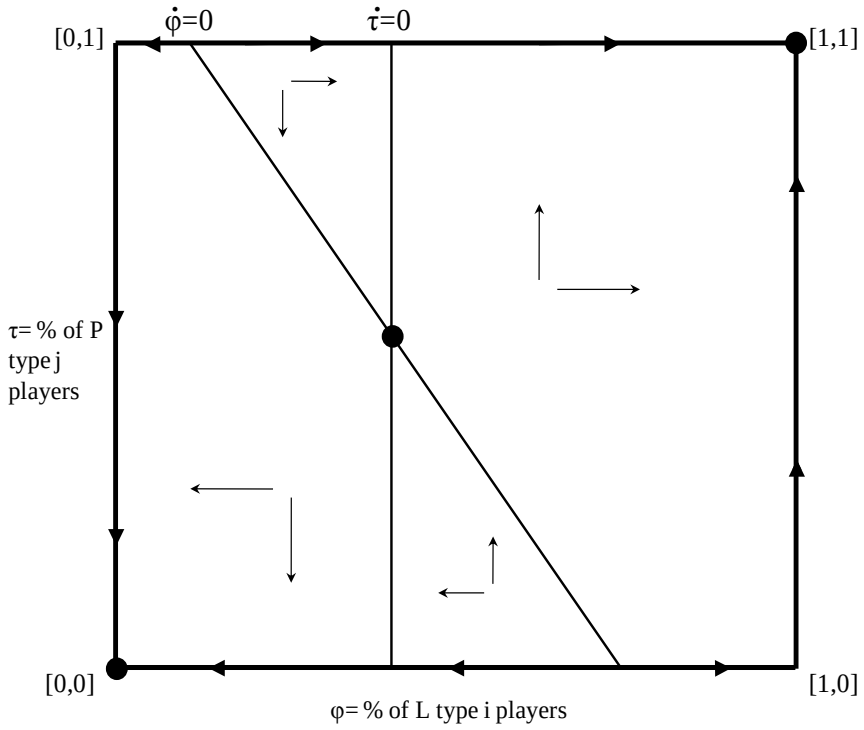
$$(a_1 - a_2)\varphi + l\tau - r = 0$$

we get the interior fixed point $(\varphi^*, \tau^*) = \left(\frac{\delta_1 + \sqrt{{\delta_1}^2 + 4a_1\delta_2}}{2a_1}, \frac{r}{l} - \frac{(a_1 - a_2)(\delta_1 + \sqrt{{\delta_1}^2 + 4a_1\delta_2})}{2a_1 l}\right)$

[33] Beware that there are two roots of the second equation, yet one of them is always negative, since the opposite requires that $4a_1\delta_2 \leq 0$.

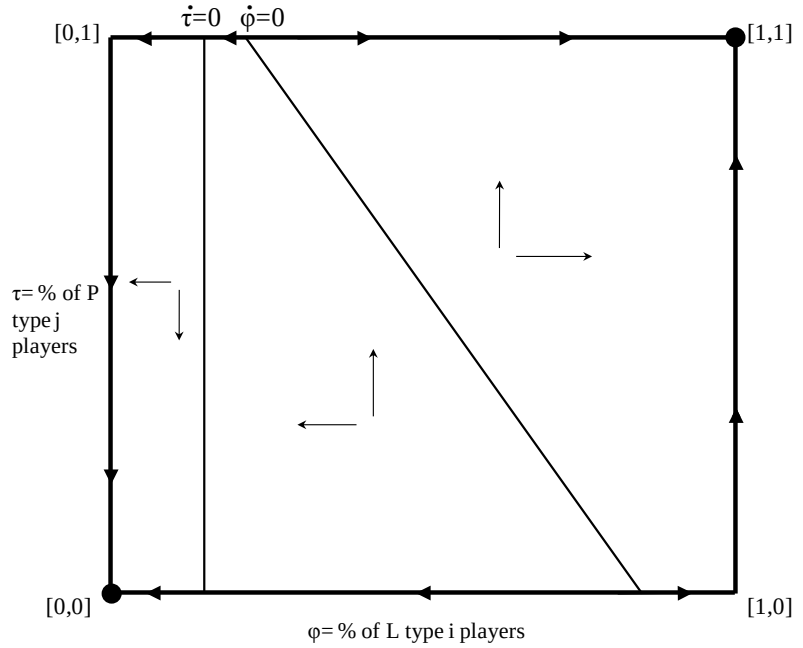
and $(\varphi^*, \tau^*) = (1, 1)$ that are stable (see Figures 1b and 1c below). Overall, there are two likely outcomes, one with high frequency of copylefters and partners, and another with high frequency of copyrighters and other employees.

In Figure 2a, we depict convergence to stable states (0,0) and (1,1) under different initial conditions.[34] A more complete analysis of the dynamical system could be provided, in which the basins of attraction of the two stable states are studied with respect to changes in the parameter values. The result of such an analysis for the parameter a_1 shows that, as we expect, an increase in the value of it leads to a larger basin of attraction for copylefters-partners equilibrium (Figure 2b,c).

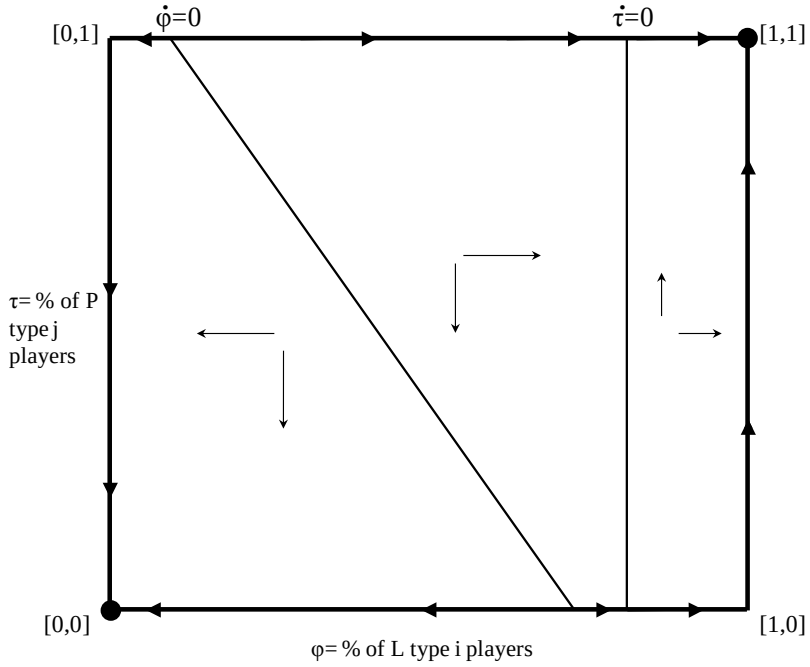


(a)

[34] We have used the following parameter values for the figure: $a_1 = 0.3, a_2 = 0.1, \delta_1 = 0.05, \delta_2 = 0.1, l = 0.1, r = 0.15$.

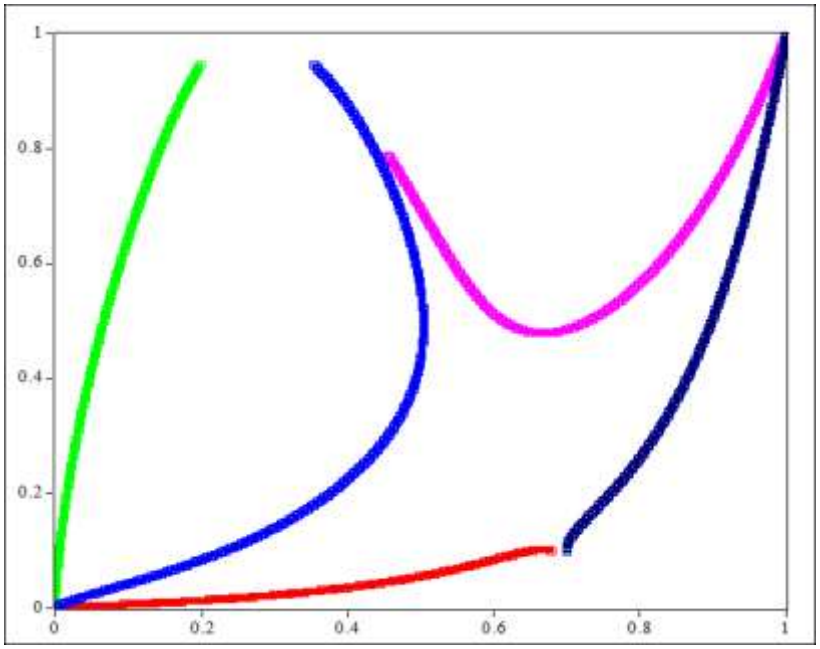


(b)

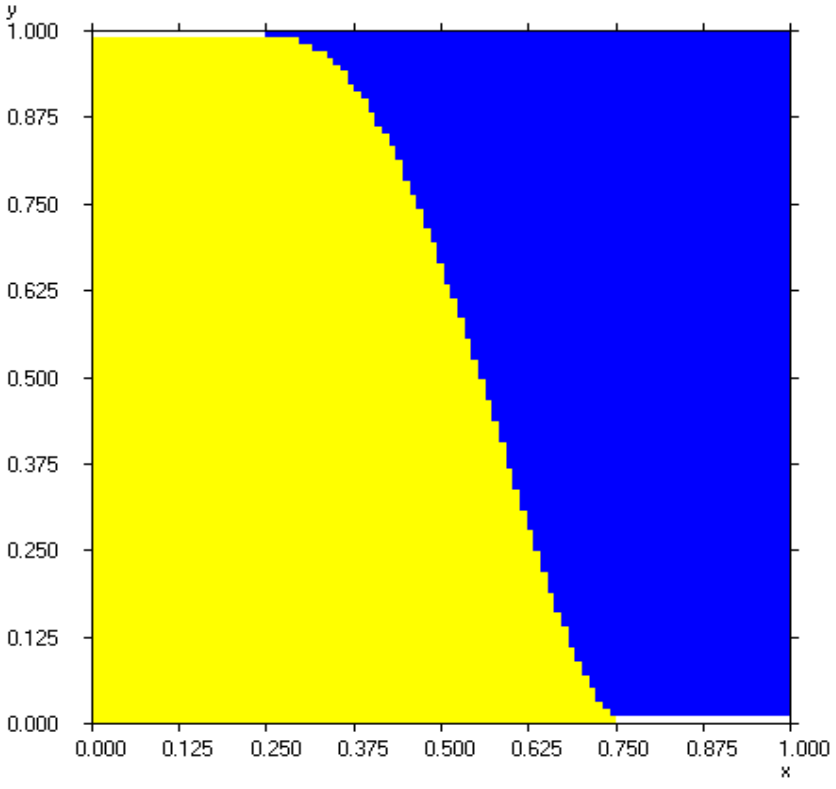


(c)

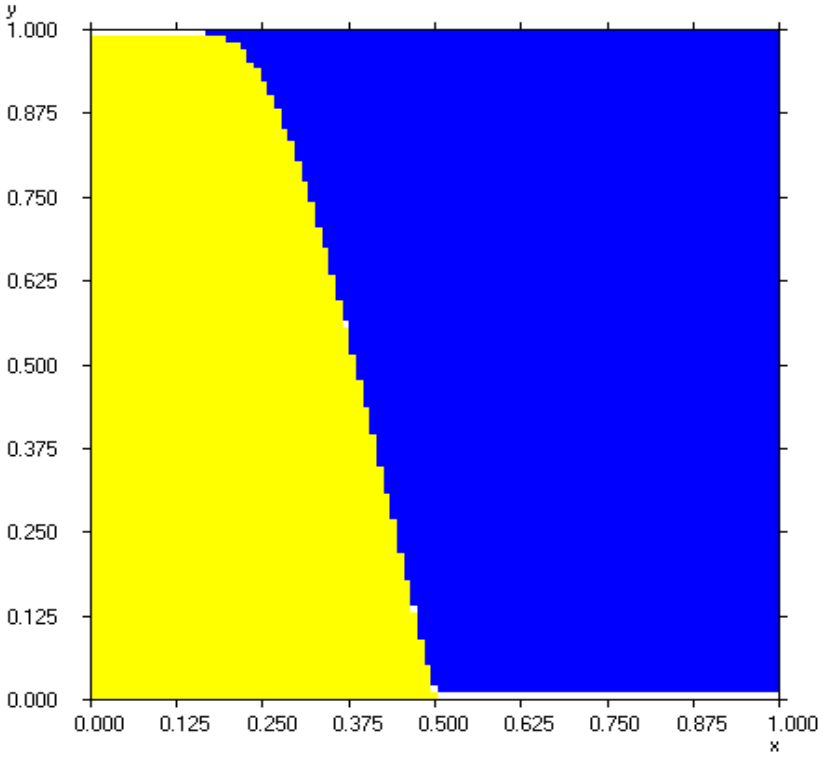
Figure 1: Co-evolution of rights and workers' types. Note that convergence to the two stable states (0,0) and (1,1) can be seen by arrows indicating disequilibrium adjustment process (Note: x-axis is % of L type i players, and y-axis is % of P type j players).


1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1

(a)


y
1.000
0.875
0.750
0.625
0.500
0.375
0.250
0.125
0.000
0.000
0.125
0.250
0.375
0.500
0.625
0.750
0.875
1.000
x

(b)



(c)

Figure 2: **(a)** Convergence to the stable states (0,0) and (1,1) under different initial conditions. Basins of attraction of the stable states (0,0) [yellow], and (1,1) [blue] for **(b)** $a_1 = 0.3$ and **(c)** $a_1 = 0.4$ (Note: x-axis represents % of L type i players, and y-axis represents % of P type j players).

4. Discussion

It is foremost the factory system that transferred the decision making autonomy of workers on how intensely to work to the employer in the 19th century. Scientific management, at the dawn of the 20th century, intensified this transformation process. In order to obtain control over technical knowledge, particularly those produced and possessed by employees, all possible brainwork was removed from the shop floor and concentrated in the planning department (Braverman 1974, Edwards 1979). The end result was the minimization of the skill content of work.

As we have pointed out in the previous sections, this type of work relation entails control over the intellectual assets produced by the employees. It is further used to continually shift information asymmetry in the employer's favour. In the knowledge economy, firms could adopt technologies that favour disembodied intellectual capital at the expense of embodied worker skills, in which they derive rent r from the former. Equations [2b] and [4] capture the logic of such a relation: We may call it classical (or capitalist) firm. Yet, this type of institutional arrangement may also create a trade-off between controlling and coordinating employee behaviour, and the need for incentive systems for supporting motivation and creativity of the same employees. To put it differently, the very same system that grants exclusive rights to the managers (and hence the owners of intellectual assets) undermines the incentives for employees to invest in intellectual skills.

Under an alternative institutional arrangement, when no single person has exclusive rights over the use of intellectual assets, partners could reciprocate and invest in intellectual skills (equations [1a] and [3a]). In other words, partnership under non-exclusive IPRs regime entails firms that use non-rival knowledge in the production process (Pagano and Rossi 2011). Under a disclosure-prize driven system, small firms could be competitive, since they could use freely available disembodied knowledge in order to improve members' skills. As we have said, the allocation of rights to workers may be more efficient due to its transaction cost saving features, since idiosyncratic knowledge in the hands of workers can be better used when workers assume rights in the organization. Hence, workers being integrated into the firm treat work as a more rewarding experience. Yet, we have not witnessed the proliferation of this organizational form.

Interestingly, free and open source software production (F/OSS), which is another example of sharing non-rival knowledge in the production process is

relatively successful. In F/OSS, voluntary contribution of agents[35] and rich information exchange among them creates substantial information gains (Benkler 2002, 2006). Yet, there are some particularities of this mode. First, instead of full time contribution of few agents, there is instantaneous contribution of many, which is made possible by fine-grained and modular production (Benkler 2002, 2006). The latter requires production processes to be dividable into components, each of which runs independently. This type of modular production[36] enables the participation of many individuals simultaneously on different components of the project and increases return to sharing it, i.e. a_1 is high. The former captures the fact that each process is small in size, hence each agent contributes small piece of work, in other words δ_1 is very small. Last but not least, in this form, most of the time, it is the users who do product and process developments. Users are producers that constitute an innovation community (von Hippel 2005, Baldwin and von Hippel 2010). Thereby, there is no labour cost w associated with i agents playing L in equation [1a]. In essence, commons based peer production represents a *novel* way to organize production in the knowledge economy.[37]

As rightly emphasized by the literature, workers' control is not about the ownership of (mainly) physical assets, but about who controls the knowledge base of the organization. In this regard, partnership under private IPRs regime, i.e. equations [2a] and [3b], has somewhat interesting implications. Knowledge intensive technology favours workers due to the difficult to monitor nature of embodied knowledge. Giving rights to workers is a viable alternative in order to provide incentives to invest in human intellectual skills related to this hidden knowledge.

[35] Voluntary collaboration may be due to extrinsic (reputation, user needs, and benefits to individual users via learning and using the developed products), and/or intrinsic (gift giving, reciprocity, and pleasure of creation) motivations (Rossi 2004).

[36] See Simon (1962) on modularity. See Landini (2012) on modularity in software production.

[37] In addition to technology, the resistance of many programmes to the privatization of the software domain allowed relatively easy adoption of this new technology (Moody 2001, Stallman 2002).

On the other hand, disembodied knowledge could easily be privatized. In other words, exclusion of others from the usage of knowledge is possible. If there exists private property on intellectual assets, initial distribution of IPRs in the hands of few owners will inhibit the proliferation of modes that require accumulating difficult-to-monitor intellectual skills for workers (see, for example, Earle et. al. 2006). IPRs will favour the concentration of difficult-to-monitor skills in the hands of these few owners. Non-owner workers face the problem that human capital may be specific to an intellectual asset, whereas owners have sufficient safeguards to develop the ability to improve their skills. In turn, lack of skills on the side of workers will render difficult the acquisition of intellectual property (Pagano and Rossi 2004).

Lastly, equations [1b] and [4] capture the logic of state financed organizations such as public research laboratories and universities. Inquiry based on non-exclusive property rights is also the characteristic of this organizational form. All intellectual property claims on knowledge are voluntarily given up by researchers, and (usually) all parties have equal access to it. In other words, public research institutions are oriented towards the production of freely circulating public knowledge driven by reward systems.

However, public system of research, i.e. universities and public research laboratories, has traditionally focused on scientific activity. It is usually subsidised by public authorities, since, basic research conducted by open science institutions provide a common knowledge base that is used by for-profit organizations for further commercial applications. Universities and research institutes have assumed critical roles in creating the broader technical knowledge base, which is transformed to commercial products via private profit-seeking firms (Chandler 2005, xiv). For example, Mokyr (2002) argues that the growth of common pool of this type of knowledge was crucial for the development of technological knowledge in the industrial revolution.

As we have already pointed out, private profit opportunities alone are not likely to draw enough resources into basic research (see Section 2.1). Keep in mind

that this equilibrium is never stable in our framework. They rely on public subsidies, and the reason behind this support is crucially based on both basic research and commercial application distinction, and the belief that there is underinvestment by private agents in the former. If this is the case, the erosion of this distinction may have long lasting implications for the survival of public research institutions, since these two realms of knowledge production become rivals. Today, it is difficult to establish such a clear-cut division between the kingdom of technology and republic of science.[38]

Therefore, not surprisingly, many observers point out that universities have begun to seek patents impeding the sharing of information that typified past experience (David 2004b, Benkler 2006).[39] We see a surge in the privatization of knowledge domains that were previously public. The problem is especially severe where basic scientific research is very close to commercial product development, e.g. biotechnology. In such an environment, open science institutions may start imitate business firms. Indeed, behavioural shift in this direction is already visible (David 2004a, 2004b). This trend has the danger of abolishing the role and importance of open science in backing technological progress (Mokyr 2002; Pagano 2008).

The developments in the last few decades may signal a return to the pre-industrial revolution production environment in which the classical (capitalist) firm was not the dominant form of production. Today, organizational variety includes for-profit organizational forms that are not based on classical employment relation as well as novel models such as commons based peer production. Yet, technological change does not occur in an institutional vacuum. The privatization of useful knowledge and the erosion of basic science-commercial application distinction affect the fate of alternative forms. Therefore, if the logic of property rights is to be applied to knowledge without any qualifications, it may create barriers of entry for alternative organizational forms.

[38] See Dasgupta and David (1994).

[39] For an overview, see Hall and Harhoff (2012, 24-27).

In this regard, laws and regulations form an important domain in which the battle over the organizational ecology of the knowledge economy is fought. As Benkler (2006) argues, an economic policy allowing yesterday's winners to dictate the terms of tomorrow's economic competition may be problematic. Policy making should, at least, ensure that regulations in the realm of IPRs do not permanently favour proprietary models at the expense of disclosure driven practices. In this regard, governments have done very little to create an infrastructure to support the practice of open innovation (Baldwin and von Hippel 2010).

On the other hand, the lobbying efforts of large firms that collect rents if intellectual property is enforced are very strong. It skews the institutional ecology in favour of business models and production practices that are based on exclusive property claims, even though the social trend is pushing in the opposite direction, as in the case of F/OSS. Hence, complementarities across several domains may necessitate intervention by the state to sustain organizational diversity in the knowledge economy.

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CHAPTER 3

INSTITUTIONAL COMPLEMENTARITIES AND PROPERTY RIGHTS-TECHNOLOGY EQUILIBRIA UNDER KNOWLEDGE INTENSIVE TECHNOLOGY

Abstract

The unprecedented development of intellectual property rights (both in scale and scope) has been one of the most important factors in the transformation of the world economy over the last three decades. We argue that, at least in part, economic importance of knowledge has brought an overreaching enclosure movement on it. Intellectual property rights (IPRs) regime protecting the knowledge base of firms deprives knowledge workers of owning the intellectual assets developed in the production process. This development, in turn, (a) has damaging consequences on the knowledge workers' skills; thereby (b) the rise of a virtuous cycle between non-exclusive property rights and workers' skills is prevented.

JEL Codes: K11, L23, O34

Keywords: Intellectual property rights, knowledge intensive technology, institutional complementarities

1. The Organization of Work under Knowledge Intensive Technology

The nature of knowledge intensive technology has changed the foundational image of production, which is a manufacturing enterprise where raw materials are transformed by physical labour and machine power. This mode of production associated with industrial technology substitutes human intellect in

many of the processes associated with production. Under this method, production workers use their bodies, which keep them distinct from those who employ them, i.e. managers. To put it differently, it is *effort* that is the key element in the production process, since physical effort and intellectual skills of workers are de-coupled. In turn, managers face the continual problem of getting workers to do what the organization requires of them, i.e. managers are the functionaries of capital (Screpanti 2001). Standard methods for intensifying effort are declining union power, and managerial pressure. Broadly speaking, this type of work is characterized by low wages, low training, and frequent layoffs (Green 2006).

The rise of the knowledge content of work in the last three decades has concretized tacit and dispersed character of knowledge in the hands of workers (Zuboff 1989, Hodgson 1999). Mastering this new environment requires developing *intellectual skills*, and theoretical conception of the work process. In this regard, knowledge intensive technology has the potential to free workers for a more comprehensive and abstract learning where work requires intellectual skills. In other words, while under the industrial technology the worker is only a source of physical effort, under knowledge intensive technology he is also a source of intellectual skills (Zuboff 1989).

If returns to this type of labour are relatively high in the knowledge economy, production technology can evolve in such a direction that workers acquire more skills, and eventually rights in the production process. Moreover, setting aside efficiency considerations, such a development is a desirable outcome also because it may mitigate the undemocratic and unequal nature of employment relation that has prevailed under industrial technology (see Rowthorn 1974, Archer 1996, Bowles and Gintis 1996, Screpanti 2001). Yet, this mode of production may not only raise the returns to skilled labour, but also may increase labour costs, and lessen the firms' ability to reduce those costs without consent from workers (Green 2006).

Even though the developments in technology favour the employment of skilled labour in the production process, constraints in other institutional domains may prevent such a development. In other words, managerial decision making does not take place in a vacuum. Production managers face a set of rules that are not fully under their control, e.g. property rights regime. The rules of the game, i.e. IPRs regime, have changed profoundly (both in scale and scope) over the last three decades. Indeed, as some researchers note, the unprecedented development of IPRs has been one of the most important factors in the transformation of the production organization in this period (Orsi and Coriat 2006, Coriat and Weinstein 2011).

Progressive tightening of the IPRs regime and the extension of patentable subjects to new areas such as software, business methods, and living entities are among the developments that characterize this period. For example, in the US, Patent and Trademark Amendments Act – well known as Bayh-Dole Act (1980) – allowed public research institutions to patent their findings.[40] Yet, researchers insist that information is not like any other commodity traded in markets, since owning an abstract idea means that you have the right to control all copies of that idea (Boldrin and Levine 2008). Private property on knowledge creates global excludability, i.e. IPRs create rights for an individual or a firm that involve duties for the rest of the people all around the world (Pagano 2007a, b).

Another important aspect of the developments that have taken place in the realm of IPRs regime is its effect on the knowledge workers' rights in business firms. Most workers do not hold property rights on inventions produced on the job by them. In other words, ownership of intellectual assets usually resides in firms. The default rule says that the employer should retain title to any patentable inventions produced by workers since the latter have already been compensated through wages. This legal transformation, i.e. from a relatively

[40] The field of IP law has been a battleground for interest groups both in national and international level (Salzberger 2011, Lessig 2004, Chang 2001, 2002). See Machlup and Penrose (1950) for an early treatment of the issue. In practice, the commodification of knowledge assumes many forms, that is, intellectual property is used to describe several legal regimes such as copyright, trade secrets and patents (Besen and Raskind 1991). For classical treatments of economic nature of information, see Nelson (1959) and Arrow (1962).

pro-employee legal standard to contemporary pro-employer rules, took place steadily between 1830 and 1930 (Fisk 1998). The driving force behind this change was the rise of corporate industry and the institutionalization of R&D activities within business firms, which progressively eliminated the importance of individual inventor (see also Schumpeter 1954 [1942]).

Therefore, in several industries, even though employing skilled workers may be highly favoured due to higher returns to this type of labour, a typical employment contract assigns title to any invention made by these workers during the employment period to the firm (Merges 1999, 7). This type of ownership regime, in turn, dampens incentives to invest in skills on the side of knowledge workers. We may expect a tendency towards underinvestment in intellectual skills on the side of workers, since a worker who has acquired skills specific to that piece of intellectual property may be denied the access to it in the future (Pagano and Rossi 2004, 2011).

Of course, ownership of inventions may not be the only form of employee compensation. Higher wages, for example, is a way of compensation for knowledge workers. Another such effective compensation may be the escape batch allowing workers to exit a firm before an inventive concept has taken on a concrete form (Merges 1999, 3). Yet, even though other compensation schemes exist, a property rights regime, which determines the distribution of intellectual assets among the firm and knowledge workers may have a significant effect on the performance of these very same workers, and hence the firm.

This paper tries to address all the issues raised above in a single framework. To do that, we rely on the literature on institutional complementarities. In particular, we focus on the interplay between technology and property rights, keeping in mind possible hazardous effects of certain property rights regime on knowledge workers' skill acquisition. Institutional complementarities suggest that a particular type of coordination mechanism or institution in one sphere tends to favour complementary institutions in other spheres.

Complementarities can arise in various levels of economic analysis. For example, a firm may encounter several coordination problems in its internal (workers) as well as external (financiers) relations (Hall and Soskice 2001, 7).[41] These complementarities may be related to manufacturing, as well as marketing (Milgrom and Roberts 1990a, 513-514). In essence, coordinating decisions at the corporation level is a multidimensional task, and the transformation of production organization usually entails simultaneous changes in several domains. In the context of our paper, it is the interplay between technology (workers' skills) and property rights (IPRs), which constitutes an uncoordinated simultaneous change in different domains of business firms' strategy (see Pagano 1993, Pagano and Rowthorn 1994).

2. Property Rights - Technology Equilibria in the Firm

Changes in production organization are changes in both property rights structure and technology. When change is simultaneous, it is also uncoordinated. Property rights structure of the corporation is usually taken as given by production managers when organizing production, and vice versa. Institutional complementarities arise since different agents (shareholders and production managers) not only face different domains of choice, but also do not coordinate their choices across these different domains, i.e. choice in one domain acts as an exogenous parameter in the other domain. Complementarities between property rights decisions (by shareholders) and technology (by production managers) are crucial in understanding the developments that have taken place under the knowledge intensive technology. Moreover, when analysing this interplay, the effect of several IPRs regimes on the knowledge workers' skill acquisition decisions must be taken into account.

[41] For an overview of the concept of institutional complementarities, see Milgrom and Roberts (1990a,b); Aoki (2001). For studies relying on the concept of institutional complementarities in explaining institutional diversity, see Hall and Soskice (2001).

The framework we develop, in addition to the analysis of Williamson (1985) that describes a direction of causality moving from technology to the property rights structure, stresses that the opposite direction of causality may also hold: Property rights structure of the firm might influence the choice of technology, i.e. employment of skilled labour. When both directions of causality hold, some self-reinforcing equilibrium could prevail, in which initial conditions regarding property rights and technology may affect the organization of production under knowledge intensive technology. Hence, there may be path dependent co-evolution between technology and property rights, since property rights structure may differ (e.g. across industries or countries), and initial conditions may affect the evolution of the system.

Below, we develop a model that explains the existence of institutional complementarities between technology and property rights structure, where multiple organizational equilibria characterize the organization of production.[42]

We distinguish two domains of choice:

(i) property rights domain

(ii) technology domain

For simplicity, assume that there are two main types of IPRs regime regarding workers' rights. Assume that when the owners of the organization (shareholders) adopt a strong intellectual property rights regime, knowledge workers do not acquire any rights on the inventions made during the production process. This type of regime signals that the firm seeks for appropriate safeguards for knowledge produced in the firm; since, in the case of job termination (before the project finalizes), owners can use the assets, and recover the amount invested in the project, since useful knowledge is retained by the firm.

[42] For a similar model (on institutional complementarities between technology and finance) see Pagano and Nicita (2002).

On the other hand, assume that, under an alternative (weak) intellectual property rights regime, the firm favours knowledge workers' rights on the inventions made during the production process. This type of firm may make a higher ex post return, if knowledge workers are sensitive to such a compensation schema. Yet, at the same time, it is a risky choice, since skilled knowledge workers could quit the job before the project is finalised, leading to the loss of valuable knowledge (hence assets) for the firm.

In particular, property rights decision is influenced by owners' preferences over expected income on projects when employing skilled (intellectual) workers, and the loss of useful knowledge in the case of job termination. Production technology based on unskilled (general purpose) labour, which is indifferent to alternative property rights regimes, yields moderate gains to the corporation, but provides safeguard in the case of job termination. Therefore, when returns on skilled labour is negligible, we may expect a strong intellectual property rights regime, since the firm does not receive any extra returns stemming from the employment of skilled labour. Moreover, in the case of job termination shareholders perceive returns on investment generated by that general purpose labour.

Employing general purpose labour may be less attractive for shareholders when extra return to skilled labour is relatively high. In this case, investment in skilled labour is worth pursuing despite the risk of job termination if the technology generates extra returns. Thereby, owners will favour weak property rights scheme, despite the possibility of job termination. Under this case, shareholders will be more interested in investments that are characterized by higher returns (due to returns stemming from employing skilled workers) in no job termination event.

In the technology domain, production managers determine technology, i.e. they choose between employing skilled or unskilled labour that maximizes profits taking as given the property rights structure of the firm. When strong intellectual property rights regime prevails, there will be bias in favour of unskilled labour.

On the contrary, when weak intellectual property rights regime prevails, managers will employ skilled labour due to extra returns stemming from this type of labour. As we have discussed in the previous section, the realization of extra returns is highly unlikely under strong property rights regime, since workers will be reluctant to invest in their intellectual skills, and hence will not invest in intellectual skills due to the disincentive effect of the incumbent (strong) property rights regime.

In essence, production managers choose between employing unskilled (l), and skilled (L) labour. When the degree of skilled labour increases, owners will try to adopt strong property rights structure, and appropriate the extra returns generated by skilled knowledge workers. Yet, this configuration, i.e. strong property rights and employing skilled labour is difficult to be accepted by the managers due to the lack of extra returns to the firm. In our framework this is so since returns to skilled labour are only realized under weak intellectual property rights regime.

In the property rights domain, on the other hand, owners determine the property rights structure of the firm. When there is weak intellectual property rights regime there is an opportunity to employ skilled labour by managers due to extra returns to skilled labour. The choice of generic labour will be an inefficient outcome once the managers receive incentives to invest in production methods with higher returns, i.e. employment of skilled labour. Below we show that some self-reinforcing equilibrium could prevail between technology and property rights domain. Now, we clarify the conditions for such an outcome.

Formally, assume the technological structure of the firm is given by the ratio (l/L), where L indicates the amount of skilled labour, and l indicates the amount of unskilled labour with l, L>0.[43] The technological choice domain is thus given by the values of l/L which fall on a range that goes from very general purpose labour technology (denoted by T_g) to an intellectual one (denoted by T_i), such

[43] Note that throughout the paper unskilled and general purpose labour; and skilled and intellectual labour are used interchangeably.

that (l/L) is greater under the former technology. Finally, we assume that output is a linear function of the two types of labour (see equations 1 and 2 below).

Assume that owners may select a property rights' scheme that belongs to either weak intellectual property rights regime (denoted by P_w), or strong intellectual property rights regime (denoted by P_s). Let r be the economic return generated by unskilled labour, while R is the economic return generated by skilled labour. R also denotes no job termination extra return received by owners under weak intellectual property rights regime. As we have pointed out above, this extra return is not realized under strong intellectual property rights regime due to its disincentive effect on skilled workers. On the other hand, suppose that z_k, with k=(w,s) is the return perceived by the firm in the case of job termination with probability $(1-\varphi)$, where $0 \leq z_w \leq z_s \leq r$. In order to simplify the model, we assume, without loss of generality, that when R>0, $z_w = 0$, and $z_s = r$. What this assumption says is that, in the case of job termination, under strong IPRs regime, the firm can later use (or sell) the intellectual assets, and recover the amount invested in the project, since useful knowledge is retained by her. Under the alternative regime, such an option is impossible, because intellectual assets created during the project are not (legally) retained by the firm.

Assume also that the costs of employing unskilled and skilled labour are given by $c(l)$ and $C(L)$ respectively. In our schema, this cost comprises of wage payment and monitoring cost associated with un-skilled and skilled labour with the latter being greater than the former, such that $C(0) \geq c(0)$ and $C'(L) \geq c'(l)$. It is so, since we assume that, in addition to receiving higher wage, skilled labour is difficult-to-monitor. Overall, from the above formalization, we can see that when owners select a property rights scheme like P_s rather than P_w, they reveal alternative preferences over the ratio l/L expressing the technological structure of the firm.

Denote now by π_w and π_s, the profits of weak property rights and strong property rights contractual schemes, respectively.

$$\pi_w = \varphi(rl + RL) + (1-\varphi)z_w l - [c(l) + C(L)] \quad (1a)$$

$$\pi_s = \varphi r(l + L) + (1-\varphi)z_s l - [c(l) + C(L)] \quad (2a)$$

When $z_w = 0$, and $z_s = r$; we have,

$$\pi_w = \varphi(rl + RL) - [c(l) + C(L)] \quad (1b)$$

$$\pi_s = \varphi r(l + L) + (1-\varphi)rl - [c(l) + C(L)] \quad (2b)$$

Given the technology (l, L), owners will choose the best intellectual property rights structure. This must be such that weak intellectual property rights will prevail when their benefit, denoted by $U(P_w)$, is greater than the benefit $U(P_s)$ of strong intellectual property rights. Formally when,

$$\pi_w \geq \pi_s$$

that is,

$$\varphi(R-r)/(1-\varphi)r \geq l/L \quad (3)$$

Strong intellectual property rights regime prevails when its benefit is greater than the benefit of weak intellectual property rights regime.

$$\pi_s \geq \pi_w$$

that is,

$$l/L \geq \varphi(R-r)/(1-\varphi)r \quad (4)$$

We have already defined any two technologies T_g and T_i such that (l/L) is greater under the first technology. When we denote by P the property rights domain where the choice between the rights P_w and P_s is made by owners, and by T the technology domain where the choice between T_g and T_i is made by production managers, we can write the following remark.

Remark 1: In the domain P the benefit of weak intellectual property rights P_w over strong intellectual property rights P_s increases when T_i (instead of T_g) is chosen in the domain T.

$$U(P_w, T_i) - U(P_s, T_i) \geq U(P_w, T_g) - U(P_s, T_g)$$

Now, we could investigate what happens to different technologies for given alternative systems of property rights. Given the property rights regime (P_w, P_s), management will choose technology by maximizing profits such that

Under weak intellectual property rights

$$\text{Max } \pi_w = \varphi(rl + RL) - [c(l) + C(L)]$$

which implies,

$$\frac{\partial \pi_w}{\partial L} = \varphi R - C'(L) = 0 \qquad (5)$$

$$\frac{\partial \pi_w}{\partial l} = \varphi r - c'(l) = 0 \qquad (6)$$

Under strong intellectual property rights

$$\text{Max } \pi_s = \varphi r(l + L) + (1 - \varphi) rl - [c(l) + C(L)]$$

which implies,

$$\frac{\partial \pi_s}{\partial L} = \varphi r - C'(L) = 0 \qquad (7)$$

$$\frac{\partial \pi_s}{\partial l} = \varphi r + (1 - \varphi) r - c'(l) = 0 \qquad (8)$$

Define by L_w and l_w the arguments that maximize π_w, and by L_s and l_s the arguments that maximize π_s.

Comparing (5) and (7) we have

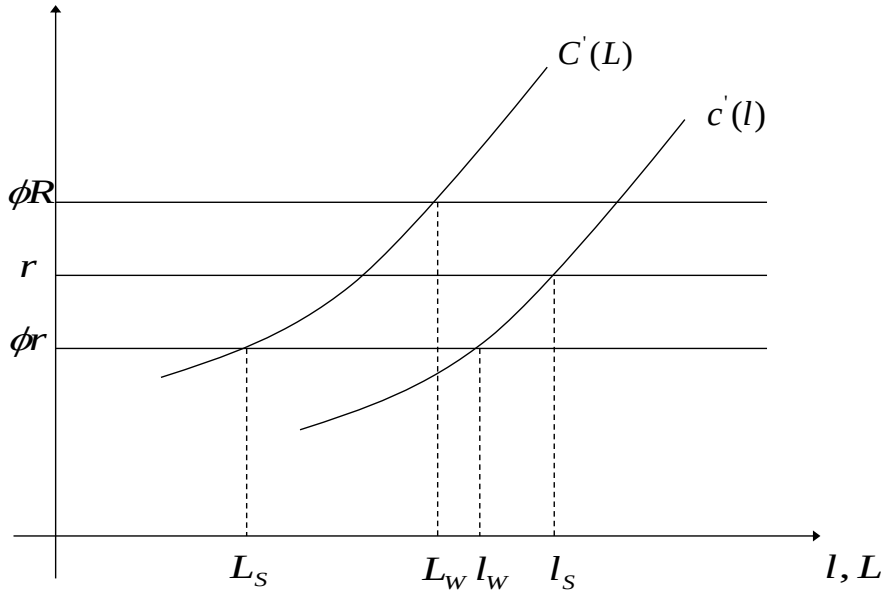
$$L_w \geq L_s \qquad (9)$$

And comparing (6) and (8) we have

$$l_w \leq l_s \qquad (10)$$

From (9) and (10) it follows that (see the figure below)

$$\frac{l_s}{L_s} \geq \frac{l_w}{L_w} \qquad (11)$$



Thereby, we can write the following remark.

Remark 2: In the domain T the benefit of a more general purpose technology increases when strong intellectual property rights instead of weak intellectual property rights are chosen in the domain of P. That is;

$$\mathrm{U}(\mathrm{T_g}, \mathrm{P_s}) - \mathrm{U}(\mathrm{T_i}, \mathrm{P_s}) \geq \mathrm{U}(\mathrm{T_g}, \mathrm{P_w}) - \mathrm{U}(\mathrm{T_i}, \mathrm{P_w})$$

These two remarks imply that multiple property rights-technology equilibria are possible where (P_w, T_i) is characterized by the complementarity of weak intellectual property rights and intellectual (skilled) labour technology, and

(P_s, T_g) is characterized by the complementarity of strong intellectual property rights and general purpose (unskilled) labour technology.

Weak intellectual property rights equilibrium is defined by the set of values for which these rights bring about the highest value to the firm given a technology T_i, and in turn a technology T_i maximizes profits under these rights. This occurs when the values of the arguments (l_w, L_w), that max (1) also satisfy (3)

$$\varphi(R-r)/(1-\varphi)r \geq l_w/L_w \qquad (12)$$

Strong intellectual property rights equilibrium is defined by the set of values for which these rights bring about the highest value of the firm given a technology T_g, and in turn a technology T_g maximizes profits under these rights. This occurs when the values of the arguments (l_s, L_s) that maximizes (2) also satisfy (4)

$$l_s/L_s \geq \varphi(R-r)/(1-\varphi)r \qquad (13)$$

Denote now

$$ER_{ig} = \varphi(R-r)/(1-\varphi)r$$

ER_{ig} expresses the ratio between the expected extra return from intellectual labour and the return from general purpose labour. Because of (11) this ratio must either fall within the interval defined by (l_w/L_w) and (l_s/L_s) or in the interval defined by 0 and (l_w/L_w), or in the interval defined by (l_s/L_s) and infinity. Thus, we have the following proposition.

Proposition 1: Multiple property rights technological equilibria exist when ER_{ig} falls between the values (l_s/L_s) and (l_w/L_w). A unique strong property rights equilibrium exists when the ratio is smaller than (l_w/L_w), while a unique weak property rights equilibrium exists when the ratio is greater than (l_s/L_s).

Proof. It follows from the fact that when

$$\frac{l_s}{L_s} \geq \varphi(R-r)/(1-\varphi)r \geq \frac{l_w}{L_w} \qquad (14)$$

Both (12) and (13) are satisfied. When

$$\frac{l_s}{L_s} \geq \frac{l_w}{L_w} \geq \varphi(R-r)/(1-\varphi)r \qquad (15)$$

(13) is satisfied but (12) is not satisfied, and finally when

$$\varphi(R-r)/(1-\varphi)r \geq \frac{l_s}{L_s} \geq \frac{l_w}{L_w} \qquad (16)$$

(12) is satisfied while (13) is not satisfied.

Proposition 1 implies that when the probability of job termination is low, and returns to skilled labour are relatively high, then only weak intellectual property rights equilibria are possible. By contrast, when the probability of job termination is high, and returns to skilled labour is relatively low, then only strong intellectual property rights equilibria are possible.

The first condition, i.e. low probability of job termination, can be guaranteed by nationwide intervention including other coordinating agents such as the state and trade unions. German and Japanese types of capitalism provide such examples (Pagano 1993, Hall and Soskice 2001). National actor and other coordinating institutions may have an effect also on the second condition, e.g. by providing vocational training. Yet, this condition may also favour the continuation of the unequal relation between firms and workers. Such a scenario means that knowledge workers of the 21th century may share the fate of clerical work of the 20th century as neatly analyzed by Braverman (1974). More on this issue is discussed in the next section.

3. IPRs Regimes and the Evolution of Work Relations

The last proposition also clarifies the extent of the viability of weak intellectual property rights regime under knowledge intensive technology. The system will move in the direction of weak property rights regime when returns to skilled labour are large enough. Yet, if initial conditions are such that the system is one

of the strong intellectual property rights regime, there will be a disincentive effect on the side of the knowledge workers to invest in their intellectual skills, which, in turn, eliminates extra returns generated by this type of labour.

The last observation is made by several researchers (see, for example, Pagano and Rossi 2004, 2011). If initial conditions secure control over intellectual assets to the corporations, this could be used by the very same corporations to continually shift the production technology in their favour. In particular, firms can adopt technologies that favour disembodied intellectual capital (that is IPRs) at the expense of embodied worker skills. Furthermore, if initial conditions favour firms, there will be a tendency towards underinvestment in the related intellectual skills on the side of workers. Continual decline of extra returns to skilled labour means only strong intellectual property rights equilibria are possible. Overall, initial distribution of private intellectual assets may create a vicious circle, since it discourages workers to invest in human specific intellective assets. While workers face the problem that human capital may be highly specific to an intellectual asset, firms have sufficient safeguards to develop the ability to improve technologies favouring incumbent property relations.

The extraction of useful knowledge from the shop floor, and its concentration in the hands of managers were the necessary ingredients of scientific management. This transformation had implications not only for the blue collar workers but also for clerical workers, whom were believed to be qualitatively different from the former due to their skill related characteristics. Yet, as Braverman (1974) explored in quite detail, the latter group shared the same fate with the former. History can repeat itself in this century by placing the ownership of useful knowledge in the hands of firms. Keep in mind that there is nothing intrinsic in labour that makes it a general purpose asset. It has been, and it will always be due to the deliberate effort of capitalists.

Arguments on the (human) emancipating nature of knowledge intensive technology may be exaggerated under the existence of multiple organizational

equilibria, since, foremost, it implies that there is no clear cut relation between production efficiency and institutional change. Therefore, the emergence and sustainability of a new organizational form, at least, require some form of protection or deliberate planning by different actors in the economy. In this vein, depending on the type of institutions regarded as more valuable and desirable for society as a whole, institutional change may be directed by policy interventions and legislative changes. As we have pointed out in the previous sections, skilling of workers and alternative IPRs regime may be favoured on democratic grounds. Researchers have been criticizing de-skilling on the grounds that authority relation that goes hand in hand with de-skilled labour is mainly due to the control of knowledge base of the firm by the owners. It is unskilled labour that produces what the management (the firm) wants under his authority. In essence, there is un-freedom and inequality in this type of relation (Rowthorn 1974, 80).

In line with our analysis, an example may clarify how of a successful change has taken place in the realm of free and open source software (F/OSS). It not only shows the relevance of initial conditions, but also the importance of considerations other than production efficiency and technology. The resistance of programmers to the commercialization and privatisation of software programs, i.e. strong intellectual property rights regime over the period of the development of software industry was crucial in the success of F/OSS (Moody 2001, Landini 2012). Therefore, in part, the emergence of an alternative was not only about its efficiency, but also about ethical concerns of many programmers, namely autonomy and freedom.

To sum up, knowledge intensive technology has the power to alter incumbent institutional structure, since sharing of essential knowledge has desirable inequality decreasing consequences. It makes viable more democratic forms of production organization (Pagano and Rossi 2011). Yet, property rights regime can continue to shift the balance in its favour, if it deprives knowledge workers of their rights to use knowledge acquired in the production process. By doing so, greater knowledge privatization may continue to keep the balance in favour

of owners (capital) hiring labour solution in spite of the fact that new technology has the potential to favour skilled labour and weak intellectual property rights regime.

4. Conclusion

The unprecedented development of IPRs has been one of the most important factors shaping production organization over the last three decades. It has been, foremost, the rising economic importance of knowledge that has brought an overreaching enclosure movement on it. We argue that, this development has hazardous effects on the evolution of work relations in the knowledge economy. IPRs regime as such deprives knowledge workers of owning any intellectual assets developed in the production process. This, in turn, not only has damaging consequences on the knowledge workers' skills, but also prevents a rise of a virtuous cycle between non-exclusive (weak) property rights regime and workers' skills.

Knowledge intensive technology has the potential to free workers for a more comprehensive and abstract learning where work requires intellectual skills. In other words, it is different from industrial technology in the sense that under the latter regime worker is a mere source of physical effort, whereas under the second mode it is also a source of intellectual skills (Zuboff 1989). Yet, changes in production organization are changes in both property rights structure and technology. As we have pointed out, this change, to some extent, is simultaneous and uncoordinated.

In particular, property rights structure of the corporation is usually taken as given by production managers when organizing production, and vice versa. Uncoordinated change, in turn, necessitates taking into account complementarities among various domains of choice, i.e. shareholders and production managers in our setting. Our analysis shows that improvements in workers' rights are possible when the probability of job termination is low, and

returns to skilled labour are relatively high. We also demonstrate that initial conditions that are characterized by strong intellectual property rights regime may have adverse effects on the evolution of work relations favouring more rights to the knowledge workers, since proliferation of production methods based on intellective skills crucially depends on incumbent intellectual property rights regime.

In the long run, strong (exclusive) intellectual property rights regime may not only prevent the rise of a virtuous cycle between weak (non-exclusive) property rights and skills, but also may block the proliferation of organizational forms based on workers' control (Pagano and Rossi 2011). In essence, if we do not want greater knowledge privatization to continue to push the balance in favour of owners (capital) hiring labour solution, institutional intervention by different actors is needed, since institutional complementarities necessitate active economic policy making for institutional change.

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