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Organizational Forms in the Knowledge Economy: A Comparative Institutional Analysis

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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: Institutional complementarities, organizational forms, technology, intellectual property rights

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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.[1]

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.[2] 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

[1] 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).

[2] 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.

employment relation as the dominant form of work organization. It is one of the fundamental characteristics of modern societies, which we live in (Simon 1979).[3]

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,[4] 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 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

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

[4] 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.

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.[5] 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 accumulate idiosyncratic knowledge related to their skills (see also Pagano and Rossi 2011).[6]

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.

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

[6] 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).

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.[7] 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 of Nelson (1959) and Arrow (1962), stresses the public good (non-excludable and non-rival) nature of information.[8]

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).[9] Since then, the existence as well as the content of IPRs regime have been a battle ground for interest groups all around the world.[10]

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[7] 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).

[8] 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.

[9] 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).

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

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 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.[11]

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).[12]

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.[13]

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.[14] Several studies document that the patent system did not play a crucial role even in major

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

[12] 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.

[13] 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.

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

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.[15]

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.

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).

[15] 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.

j agents \ i 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

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

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.[16]

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,

[16] 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).

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. 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

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

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

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

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

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

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)

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

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

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 $r \geq l$,[17] 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.[18] Qualitative analysis shows that the interior fixed point is a saddle (see Figure 1a below).[19] 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 $(\varphi^*, \tau^*) = (0, 0)$ 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.

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

[18] Formally, by solving the system

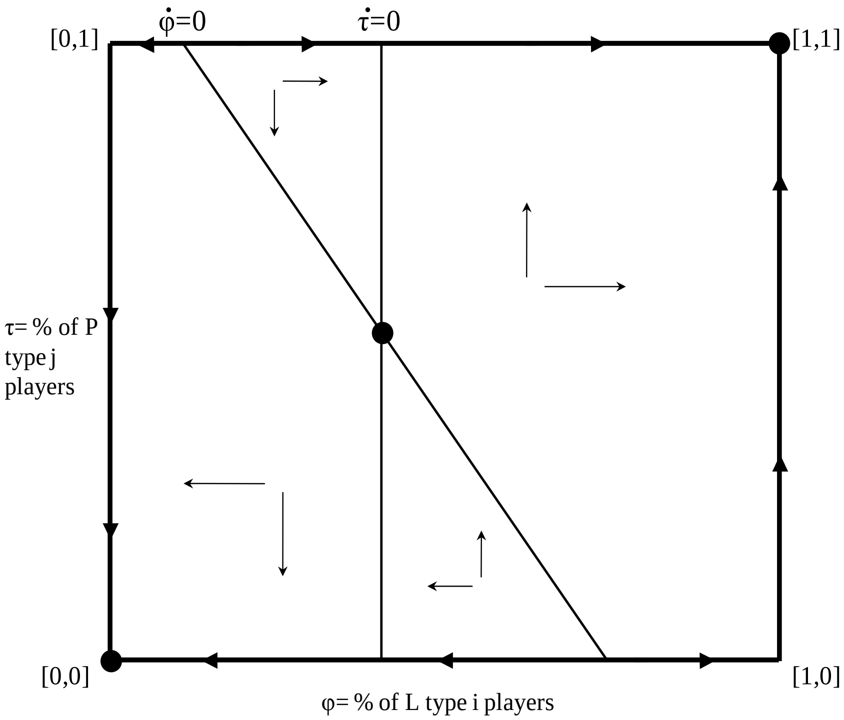
$$a_1\varphi^2 - \delta_1\varphi - \delta_2 = 0$$

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

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

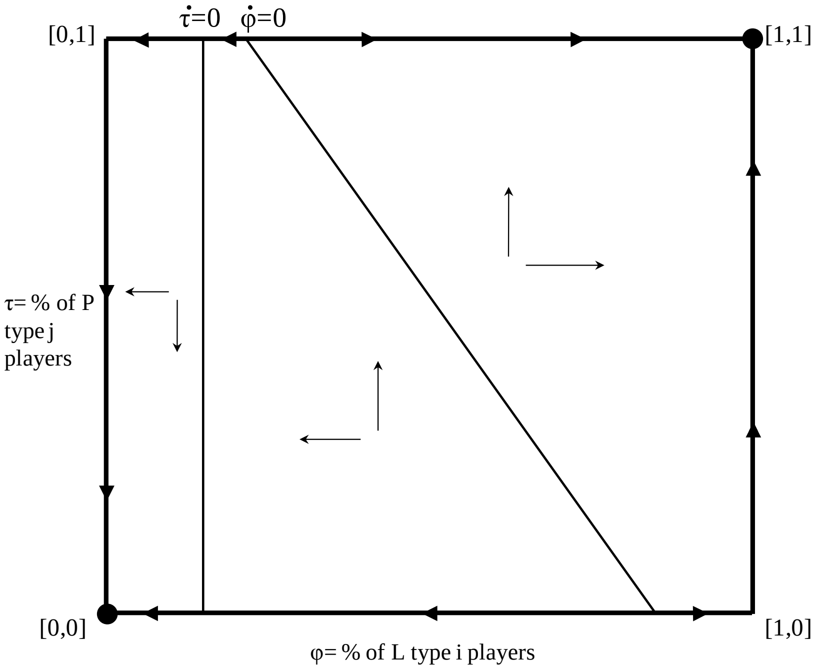
[19] Beware that there are two roots of the second equation, yet one of them is always negative, since the opposite requires that $4a_1\delta_2 \leq 0$.

In Figure 2a, we depict convergence to stable states (0,0) and (1,1) under different initial conditions.[20] 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).

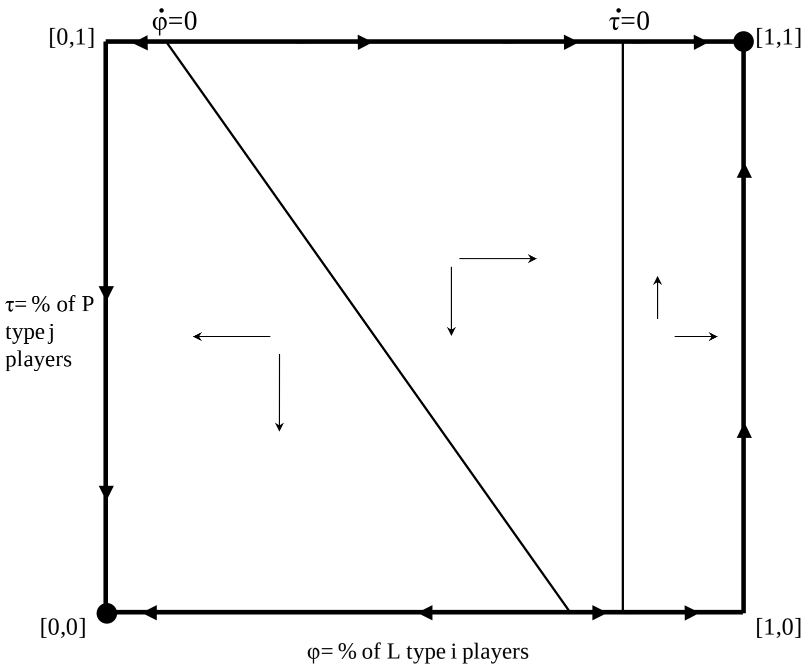


(a)

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

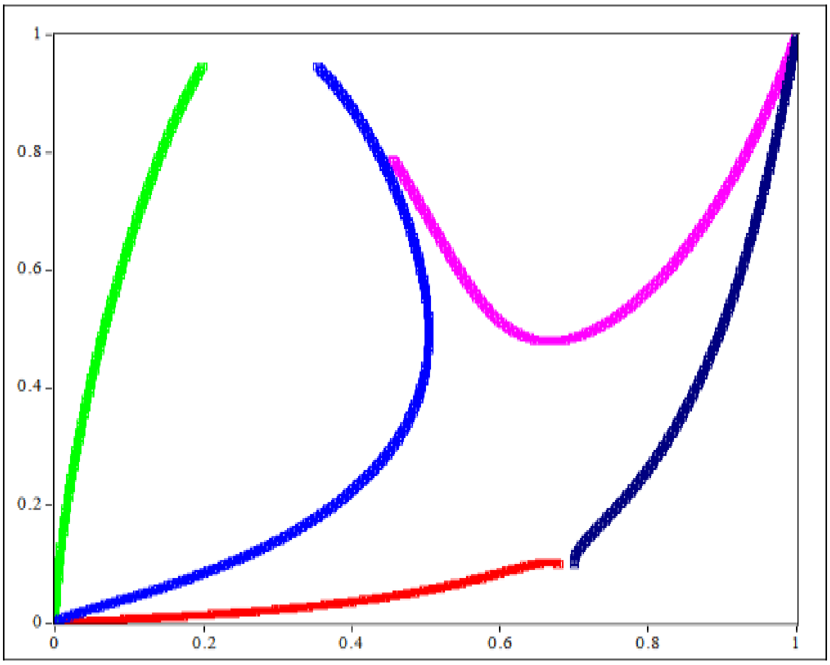


(b)



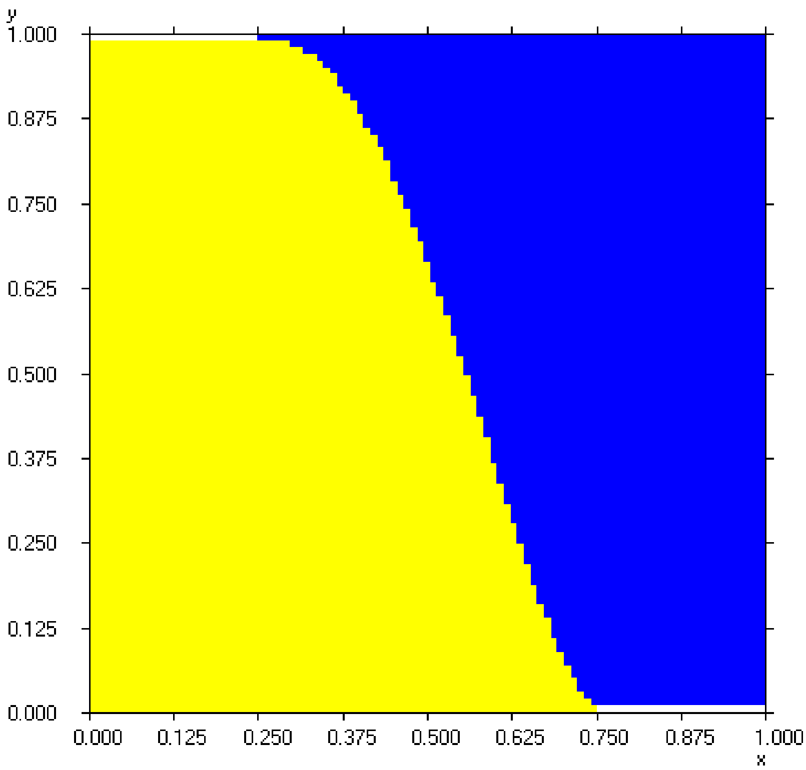
(c)

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).



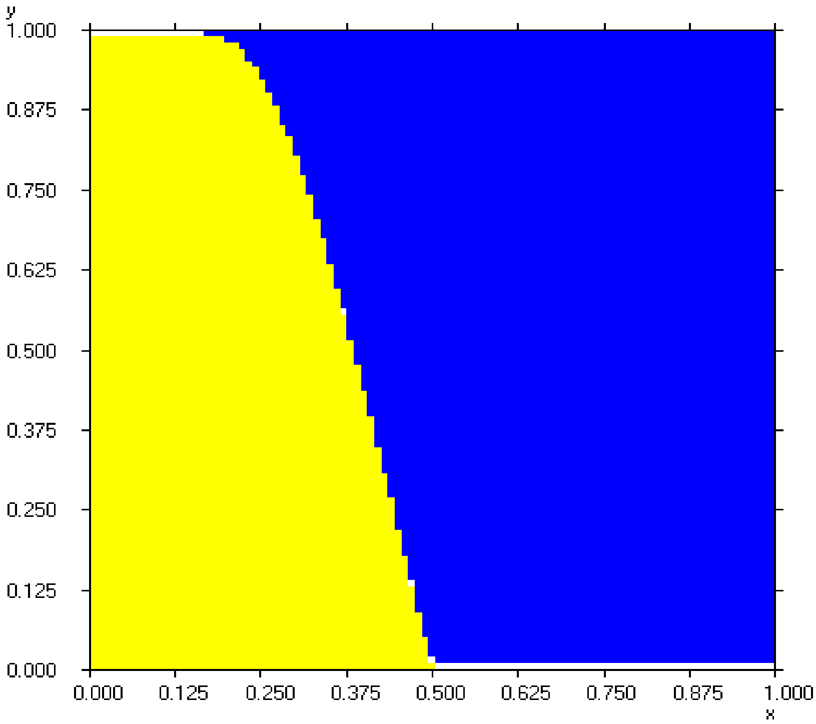
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1

(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[21] 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[22] 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

[21] 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).

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

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.[23]

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.

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

[23] 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).

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.[24]

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).[25] 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

[24] See Dasgupta and David (1994).

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

be applied to knowledge without any qualifications, it may create barriers of entry for alternative organizational forms.

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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