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Institutional Complementarities and Property Rights-
Technology Equilibria under Knowledge Intensive
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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. 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

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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 *intellective 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.

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. 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). 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 in industrial technology (see Archer 1996, Bowles and Gintis 1996, Rowthorn 1974, Screpanti 2001).

Even if the developments in technology favour the employment of skilled labour in the production process, 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. intellectual property rights (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.¹ At the same time, researchers argue 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). In other words, 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

¹ 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).

transformation, i.e. from a relatively 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 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 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 hatch 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).² 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. Transformation of production organization entails simultaneous changes in several domains. In the context of our paper, it is the interplay between technology and property rights that constitutes a simultaneous change in different domains of 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 owners) 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.

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

² 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).

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.³

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, owners can use the assets, and recover the amount invested in the project, since useful knowledge is retained by the firm.

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 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

³ For a similar model (on institutional complementarities between technology and finance) see Pagano and Nicita (2002).

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 parameter 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 put extra effort due to the disincentive effect of the incumbent (strong) property rights regime.

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.

The above scheme could be inverted to represent the property rights domain. In this domain, 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 ($L>0$) 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 ($l=L-1$, with $l, L \in (0,1)$). 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 (T_G) to a skilled one (T_S).

Assume also that owners may select a property rights' scheme that belongs to either weak intellectual property rights regime (P_N), or strong intellectual property rights regime (P_Y). Let r be the economic return generated by general purpose labour, while R is the economic return generated by intellectual 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. Suppose that z_K , with $K=(N,Y)$ is the return perceived by the firm in the case of job termination with probability $(1 - \varphi)$, where $0 \leq z_N \leq z_Y \leq r$. In order to simplify the model, we assume, without loss of generality, that when $R>0$, $z_N = 0$, and $z_Y = r$.

Assume that the cost of employing one unit of general purpose and intellectual labour, i.e. wage, are given by w , and W respectively. Finally, monitoring costs associated with unskilled and skilled labour, respectively, are $\mu_l(l)$ and $\mu_L(L)$, with the latter being greater than the former. This is so, since, skilled labour is difficult to monitor. From the above formalization, we can see that, when owners select a property rights scheme like P_Y rather than P_N , they reveal alternative preferences over the ratio l/L expressing the technological structure of the firm.

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

$$\pi_N = \varphi(rl + RL) + (1 - \varphi)z_N l - [wl + WL + \mu_l(l) + \mu_L(L)] \quad (1)$$

$$\pi_Y = \varphi r(l + L) + (1 - \varphi)z_Y l - [wl + WL + \mu_l(l) + \mu_L(L)] \quad (2)$$

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 $U(P_N)$ is greater than the benefit $U(P_Y)$ of strong intellectual property rights. This occurs when,

$$\pi_N \geq \pi_Y$$

that is,⁴

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

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

$$\pi_Y \geq \pi_N$$

that is,

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

Now define any two technologies as T_G and T_S such that (l/L) is greater under the first technology. Denote by P the property rights domain where the choice between the rights P_N and P_Y is made by owners, and by T the technology domain where the choice between T_G and T_S is made by production managers. We can write the following proposition.

Proposition 1: In the domain P the benefit of weak intellectual property rights P_N over strong intellectual property rights P_Y increases when T_S (instead of T_G) is chosen in the domain T .

$$U(P_N, T_S) - U(P_Y, T_S) \geq U(P_N, T_G) - U(P_Y, T_G)$$

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

⁴ Beware that $z_n = 0$, and $z_Y = r$.

Under weak intellectual property rights

$$\text{Max } \pi_N = \varphi(rl + RL) + (1 - \varphi)z_N l - [wl + WL + \mu_l(l) + \mu_L(L)]$$

which implies,

$$\frac{\partial \pi_N}{\partial L} = \varphi R - W - \mu'_L(L) = 0 \quad (5)$$

$$\frac{\partial \pi_N}{\partial l} = \varphi r - w - \mu'_l(l) = 0 \quad (6)$$

Under strong intellectual property rights

$$\text{Max } \pi_Y = \varphi r(l + L) + (1 - \varphi)z_Y l - [wl + WL + \mu_l(l) + \mu_L(L)]$$

which implies,

$$\frac{\partial \pi_Y}{\partial L} = \varphi r - W - \mu'_L(L) = 0 \quad (7)$$

$$\frac{\partial \pi_Y}{\partial l} = \varphi r + (1 - \varphi)r - w - \mu'_l(l) = 0 \quad (8)$$

Define by L_N and l_N the arguments that maximize π_N , and by L_Y and l_Y the arguments that maximize π_Y .

Comparing (5) and (7) we have

$$L_N \geq L_Y \quad (9)$$

And comparing (6) and (8) we have

$$l_N \leq l_Y \quad (10)$$

From (9) and (10) it follows that

$$\frac{l_Y}{L_Y} \geq \frac{l_N}{L_N} \quad (11)$$

which leads to the following proposition.

Proposition 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;

$$U(T_G, P_Y) - U(T_S, P_Y) \geq U(T_G, P_N) - U(T_S, P_N)$$

These two propositions imply that multiple property rights-technology equilibria are possible where (P_N, T_S) is characterized by the complementarity of weak intellectual property rights and skilled labour technology, and (P_Y, T_G) is characterized by the complementarity of strong intellectual property rights and general purpose 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_S , and in turn a technology T_S maximizes profits under these rights. This occurs when the values of the arguments (l_N, L_N) , that max (1) also satisfy (3)

$$\varphi(R - r)/(1 - \varphi)r \geq l_N/L_N \quad (12)$$

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_Y, L_Y) that maximizes (2) also satisfy (4)

$$l_Y/L_Y \geq \varphi(R - r)/(1 - \varphi)r \quad (13)$$

Denote now

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

ER_{gs} expresses the ratio between the expected extra return from intellectual investment and the return from general purpose investment. Because of (11) this ratio must either fall within the interval defined by (l_N/L_N) and (l_Y/L_Y) or in the interval defined by 0 and (l_N/L_N) , or in the interval defined by (l_Y/L_Y) and infinity. Thus, we have the following proposition.

Proposition 3: Multiple property rights technological equilibria exist when ER_{gs} falls between the values (l_Y/L_Y) and (l_N/L_N) . A unique strong property rights equilibrium exists when the ratio is smaller than (l_N/L_N) , while a unique weak property rights equilibrium exists when the ratio is greater than (l_Y/L_Y) .

Proof. It follows from the fact that when;

$$\frac{l_Y}{L_Y} \geq \varphi(R - r)/(1 - \varphi)r \geq \frac{l_N}{L_N} \quad (14)$$

Both (12) and (13) are satisfied, whereas when

$$\frac{l_Y}{L_Y} \geq \frac{l_N}{L_N} \geq \varphi(R - r)/(1 - \varphi)r \quad (15)$$

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

$$\varphi(R - r)/(1 - \varphi)r \geq \frac{l_Y}{L_Y} \geq \frac{l_N}{L_N} \quad (16)$$

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

Proposition 3 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 regime 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 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 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 labor 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,

skilled worker and the changes in the incumbent property rights 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 labor 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 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 favor, 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 favor of owners (capital) hiring labor solution in spite of the fact that new technology has the potential to favour skilled labor 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. 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 favor of owners (capital) hiring labor solution, institutional intervention by different actors is needed, since institutional complementarities necessitate active economic policy making for institutional change.

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