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Finance-Technology Complementarities: an Organizational Equilibria Approach⁺.

ABSTRACT

Unlike many pre-crisis contributions, Oliver Williamson emphasized how different investment projects involve different forms of governance. According to him, their specificity contents define and separate the appropriate conditions for debt and equity governances. Our paper extends his contribution by arguing that, while the degree of specificity of the technology influences the choice of the governance, also the reverse is true: equity and debt governances involve different degrees of specificity. Thus, we have to deal with finance-technology complementarities, which can generate multiple organizational equilibria. Their possible inefficiency provides an argument for regulating the limits of each form of governance and for understanding the variety of arrangements existing in real life economies.

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1. Introduction

Before the financial crisis and the great depression, according to most economists different forms of finance were not very relevant for economic performance. The Modigliani-Miller (1963) capital structure irrelevance principle had shown that, under some conditions, debt and equity systems were yielding equivalent evaluations of the firm. The different nature of the incentive problems stemming from debt and equity were, of course, recognized but it seemed that no criterion could efficiently separate the types of projects to be mainly funded with one of these two instruments. The Anglo-Saxon model seemed to mark the end of history the Corporate Law. It was the model definitively required for efficient financial corporate governance (Hansmann, Kraakman 2003).

Indeed, because of the focus on the incentive problems, a great deal of the literature expressed a preference for debt and, implicitly, for highly leveraged firms. According to conventional wisdom, increasing the debt/equity ratio seemed to have a twofold advantage. On the one hand, the repayment of the debt limited managerial digression and involved the substitution of the private benefits of control for the search of profits. On the other hand, it concentrated the ownership of the firm's shares and increased the incentives to monitor managers. The increased risk of bankruptcy, which was the other side of the coin, attracted a limited attention not only in the academic but also in the political world. Regulations dividing the realms of debt and equity, such as 1933 Glass-Steagall act, were repealed in 1999 and no real qualitative distinction between the projects to be mainly financed by debt and by equity seemed to exist.

In this framework, an important exception was Oliver Williamson's (1988) seminal paper, where he argued that the firm's financial choices between equity and debt financing were driven by asset specificity. The degree of asset specificity entailed a criterion to distinguish the cases where debt and equity funding, far from being neutral, had a comparative advantage due to the nature of firm's investments. According to Williamson's insightful intuition, the debt-equity choice was analogous to the make-buy decision, which was at the core of the Coasian transaction cost approach (Coase, 1937)¹. Firms could either rely on "external finance" (analogous to the buy-decision) in the form of debt or on "internal finance" (analogous to the make-decision) in the form of equity.

¹ For an account of the Coasian contributions see Pagano (2012).

The governance structure of debt could be outlined in a rather simple way: the firm gives back the debt increased by interest payments and accepts the interference of the funding agents on the investments decisions of the firms. Under debt financing, lenders should simply monitor that the firm keeps on being endowed with an amount of re-deployable (non-specific) capital, to be easily obtained in case of liquidation. However, in Williamson's view, this governance mode becomes increasingly costly when the most efficient available technologies require a greater intensity of specific resources. At some point, when the opportunity cost of renouncing to specific investments under debt financing is high enough, a system of equity finance becomes more convenient. Under this alternative type of governance, financiers will be remunerated with the uncertain residual profits of the firm and need some power to monitor managerial choices.

Williamson's path breaking contribution clarifies why, from the point of view of the funded party, the convenience of debt/equity ratio changes with different technologies (i. e. different degrees of specificity of the resources involved in the project). However, since, in his own approach, debt and equity are different governance structures empowering different agents, technology cannot be assumed to be exogenous and it is, indeed, well likely to be influenced by the agents holding this power. When the governance structure gives more power to debt-holders, they will try to make the firm adopt a more general-purpose technology. By contrast, when it empowers more the shareholders, they will pressure the firm to adopt a more specific technology whenever it increases profits. These conflicting interests, concerning the risks of specific assets, arise from the fact that, while debt-holders happen to be bounded in their gains by earning a fixed interest, shareholders' losses are truncated by limited liability.

The main goal of this paper is to explore the complementarities between firm's financial and technological choices². Since technology is influenced by the same governance structures that are supposed to select, there could not be a universal convergence to a *super-governance mode*, which

² Aoki examined a related problem in his (1994) seminal article which, according to Gagliardi (2014), is the first paper where the concept of institutional complementarity was introduced in economic analysis. Aoki's paper focuses on the complementarity between different workers' skills (specific or team oriented vs. general-purpose) and different financial structures (shareholders governance vs. relational banking). Since human capital cannot be owned by others or be used as collateral, Aoki's results are different from those obtained in this paper. Relational banking has an important role in Aoki (1994) contribution because he focuses insiders' skills. By contrast, as in Williamson (1988), we will assume that asset-specificity refers to non-human assets and that creditors are simply bondholders, who find it less risky to lend to firms having a low intensity of specific non-human capital. As argued later in the concluding section, a satisfactory assessment of a particular variety of capitalism requires the analysis of numerous and interrelated institutional complementarities.

selects debt and equity funding according to the specificity of the most efficient technology. Williamson observes that this super-governance mode, which he calls *dequity*, does not, indeed, characterize real-life systems, as multiple organizational arrangements exist in different sectors and in different countries. We will argue that this multiplicity and path-dependence of financial systems can be explained by the self-reinforcing complementarities existing between finance and technology.

A consequence of our argument is that state intervention must take into account real sector – financial sector complementarities: any policy acting only on one side of the governance mode may generate the risk of neglecting possible relevant feedbacks on the other side. Technological and financial choices are interdependent and their co-evolution affects the incentives of stakeholders in a rather complex way. Thus, our conclusion provides a new argument, in the post-crisis debate on corporate governance rules, for regulating the limits of each form of governance and for understanding the variety of arrangements existing in real life economies.

The paper proceeds as follows. In the following section, we extend Williamson's analysis to deal with the interdependences stemming from the complementarities between technological and financial domains. In section three, we model these complementarities and show the conditions under which multiple and path-dependent financial-technological equilibria exist. In the concluding section, we focus on the policy implications of our analysis and argue that, if there is no automatic mechanism driving debt and equity towards their efficient mix, regulations separating the two fields can improve efficiency and avoid damaging defaults. We argue that the analysis of institutional complementarities in corporate governance can help to finalize appropriate reforms in corporate governance. However, we caution that each institutional complementarity cannot be taken in isolation from the multiple complementarities that characterize modern capitalist economies. A comprehensive representation of their interactions is required to obtain a reasonable understanding of the economic system and useful tools for economic policy decisions.

2. Finance and technology: a two ways relation.

Standard theories on incomplete contracts and hold-up problems (Williamson 1985, Hart, 1995) have been typically based on the implicit assumption that parties had either ‘deep pockets’ or immediate full access to the financial resources needed to carry out a given transaction. Thus, under the standard incomplete contract framework, the choice between generic or specific investments is exclusively driven by the risk of post-contractual opportunism and it is not affected by financial constraints. Absent a credible device against a party’s renegotiation, parties in an incomplete contract would under-invest in asset specificity and produce inefficient outcomes, regardless of the way in which investments are financed.

Williamson (1988), extending his (1985) framework, analyzed the interplay between a firm’s financial structure and the specificity degree of its technological assets and organizational attributes. Williamson moved away from standard studies based on a composite-capital set-up towards a study of the investment attributes of alternative corporate projects. Rather than viewing debt and equity as merely financial instruments, Williamson considered them as two alternative governance structures and explained their emergence in terms of their comparative transaction costs, due to technological choices involving different degrees assets specificity.

In the simplest case, debt financing might be defined as a financial claim which imposes on the firm an obligation to pay a specific amount (as stipulated interest payments to be transferred at regular intervals) or, otherwise, to be forced into bankruptcy. In the event of bankruptcy, scheduled payments result in debt-reorganisation or in liquidation of firm’s assets. In the latter case, firm’s assets are liquidated and assigned to residual claimants according to their seniority. However the ex-post value of firm’s assets depends on their degree of re-deployability in alternative uses.

Since the value of the pre-emptive claims on firm’s assets declines as the degree of specificity deepens, technological choices play a very important role in the event of bankruptcy. Under this framework, the cost of debt financing increases, not only as long as ‘bet capacity’ declines, but also as assets specificity increases. If the only possibility for a firm to finance its projects is given by debt financing, the firm might be forced to some *investment rationing*, reducing the amount of specific investments in favour of greater assets’ re-deployability³. Debt financing truncates the set

³ A debt contract typically imposes a clause shifting (under the realization of some contingency) property rights on firm’s assets in the hands of senior creditors (Aghion and Bolton, 1992; Shleifer and Vishny, 1992; Triantis and Daniels, 1995; Hart and Moore, 1994 and 1995). Thus, according to Williamson (1988), the degree of assets’ re-deployability reveals the effective safeguard which is granted to bondholders in case of default.

of possible investments to be adopted by the firm: when assets are highly specific, recurring to debt financing increases (sometimes prohibitively) transaction costs.

Equity finance has very different characteristics. The main difference with debt financing, in the simplest form, is that holders of common stock are the firm's ultimate residual claimants, and that equity, being junior to debt, does not have to be repaid. The Board of Directors, elected by the pro-rata votes of those who hold tradable shares, evolves as a way by which to reduce the costs of capital for projects that involved limited re-employability. It has the power to replace management and to monitor operating investments and the way in which the firm is managed. In a sense, in Williamson's view, while debt is a market-like way of financing, equity implies some degree of proprietary integration. Because of this integration and also because of limited liability, shareholders are more interested in high returns investments in no-bankruptcy event than in higher liquidity in the bankruptcy event.

As a consequence, when assets are highly re-deployable, equity is more costly than debt, since it involves higher transaction costs (implementing a sophisticated rule for internal governance). By contrasts, when assets become more specific, debt financing is more costly, since it induces the firm to truncate the range of potential projects to be financed and realised. The conclusion reached by Williamson is thus that, depending on the degree of assets specificity, the firm can use discretionally alternative financial instruments in order to minimise the transaction costs involved in the realisation of a given project. Williamson formulated a new financial instrument, or "super-governance structure", called dequity. Under 'dequity', the best properties of debt and equity are combined because it involves that the choice of debt-equity governance is efficiently made according to the degree of asset-specificity involved in each investment project⁴.

Under the Williamsonian approach, technological structure determines the most efficient financial structure. Financial markets make the ownership structure consistent with the nature of the

⁴ Several contributions have been developed along the lines traced by Williamson and all of them share a very important feature: as long as the relationship between Finance and Technology becomes pervasive, governance problems, i.e. the problems related to the mis-alignment of managers' incentives, loose their centrality and are residually solved. Similarly to Williamson, Shleifer and Vishny (1992) developed a model which shows how investments and/or acquisition of specific assets is very difficult to finance by debt financing. P. Worthington (1995) found that the effect of cash flow on investments is larger in industries whose capital expenditure are likely to be "highly sunk" than in low capital industries. Worthington interpreted this finding as evidence that external financing of capital investment is more difficult when the assets being financed have low recovery (resale) values or are sunk (specific).

assets to be realised by the investments. The efficient technology to be adopted drives the choice of the financial structure.

Instead of converging towards a unique debt structure, corporate governance models, as they evolved in the real world, are characterized by a multiplicity of financial arrangements, leading to paths of remarkable institutional diversity within and among different national economies. In order to make Williamson's intuition compatible with this diversity, we must allow for the fact that technology is never chosen in a vacuum but is developed under pre-existing governance structures.

Williamson's analysis describes a direction of causality moving from asset specificity to firm's financial structure, and then to firm's governance. However, the opposite direction of causality may also hold: the financial structure of the firm influences the degree of specificity of the assets to be financed. As a consequence, at each moment in the firm's life, technology and finance influence each other⁵. If both the directions of causation hold, then some self-enforcing equilibrium could emerge and prevail, as the result of a complementarity relation between finance and technology. The formal notions of 'institutional complementarity' and of the related concept of organizational equilibrium (Aoki 1994, 2001 and 2011, Pagano, 1993, 2011 and 2013, Gagliardi 2014) rely on the idea that economic agents face different choice domains and do not strategically coordinate their choices across them. As a consequence, the institutional choices in one domain act as exogenous parameters in other domains and constitute the 'institutional environment' under which governance choices are made. In Williamson's approach, the only domain, over which the firm makes its choices, is the financial domain where technology is exogenously given by optimal entrepreneurial choices that are independent of the governance structure. We extend his analysis by adding a technology domain where technological choices are made under a given governance financial structure.

Thus, we assume two domains of firm's choice.

In the **financial domain (F)**, financial market intermediaries choose the financiers of the firm and, therefore, the ratio between credit and stock holders (that is the financial structure of the firm

⁵ This is related to the idea of organizational equilibria developed by Pagano (1993, 2011, 2013) and Pagano and Rowthorn (1994). In this case the two-ways causation exists between technology and workers' and capitalist ownership and, for some parameters of the model, can yield multiple equilibria where both workers' and capitalists' rights involve technological choices consistent with the efficiency of their ownership and different technologies induce ownership arrangements consistent with the efficiency of the existing technologies.

including the appropriate ratio of equity and debt), given the nature of assets or investments that actually characterize the technological structure of the firm.

In the **technological domain (T)**, the managers, having regard to the costs sustained by their financiers, choose on their behalf the nature of firms' investments (including the degree of specificity characterizing its technology), taking as given the characteristics of existing financial structure.

In the **financial domain**, financial market intermediaries make their choices regarding the best financiers for the firm, taking as given the degree of specificity of the technology. When assets are generic, market intermediaries will choose a high ratio between debt and equity holders and the firm will be governed by debt financing. Since generic assets are equally valuable in alternative uses, in the event of bankruptcy debt-holders obtain a quasi-equivalent financial return and, in this way, minimize the risks associated to default. By contrast, generic assets are less attractive for shareholders that are not truncated in their earnings. In case of default, because of limited liability, they can lose only the amount of money that have invested in the firm and they are the last to be re-paid by means of the liquidation of the assets. The opposite situation arises when assets are specific. In this case, financial market intermediaries will choose a low ratio between debt and equity holders and, therefore, the firm will be governed by the means of equity financing. Debt-governance would imply very high transaction costs to set up the appropriate contractual safeguards for debt-holders who, while being exposed to the risks of specific assets, are truncated in the appropriation of the extra-earnings that they generate. By contrast, the firm will be attractive for equity financiers who can get a share of the extra-value generated by specific asset and, in any case, face a default risk associated only to the amount to their equity capital. Thus, for increasing levels of asset-specificity, there will be a tipping point in where debt-governance is replaced by equity-governance⁶.

Let us now turn to the **technological domain**. Here, the managers, acting as the agents within a given financial structure, will choose the best technology for firm and, in particular, the ratio of specific assets. Under a system of debt-governance, managers will have a bias in favor of moderately profitable but low-risk generic investments. By contrast, when equity financing prevails, production

⁶ It is possible to raise an objection to this view of financial markets: financial market intermediaries could take into account the different technologies that bondholders and shareholders would adopt and choose the governance arrangements involving the most profitable technology. In our opinion, because of the "beauty context" problems (Keynes 1936, chapter 12), financial markets can at most select the best governance arrangements relatively to the technologies currently used by firms. In our model, we will assume that that market intermediaries achieve this level of constrained efficiency.

managers will have a bias in favor of risky but possibly very profitable specific investments that yield the greatest value to equity holders. Thus, technologies will be characterized by a higher intensity of specific asset under equity than under debt governance.

In the technological domain there exists a direction of causality opposite to the one typically outlined by the transaction costs approach. In our case, production managers acting in the interest of the present financiers would select generic (re-deployable) or specific assets according to their expected returns under a given system of financial governance. Thus, technology cannot be considered to be exogenous and it is likely to co-evolve with the governance system.

Relations of institutional complementarity characterize the interactions between technological and financial domains. A case of institutional complementarity arises when an institutional arrangement implemented in one domain might parametrically affect the consequences of other domain by changing the institutional environment. In our framework, high generic/specific capital ratio and high debt/equity ratio, as well as low generic/specific capital ratio and low debt/equity ratio are likely to be institutional complements. High values, as well as low values of both ratios, fit each other. Multiple finance-technology equilibria can prevail and, thanks to cumulative causation mechanisms, can persist over time in spite of their possible inefficiency. In order to clarify these conclusions, we formulate a simple formal model that has the purpose to deepen the analysis of the emergence and persistence of institutional complementarities between finance and technology.

3. Financial -Technology Organizational Equilibria.

Let us define, as in Williamson (1988), the firm's technological structure h as the ratio between generic and specific assets, with $h = k/K$ (with $K \neq 0$, $k \neq 0$), where $K > 0$ indicates the stock of specific assets, whereas $k > 0$ denotes the amount of general-purpose assets. The technological choice domain

of the firm is thus given by the values of h falling in a range that goes from a very generic technology (Tg), with the highest level of k/K , to a very specific one (Ts), with the lowest level of k/K .⁷

Assume also that the financial structure of the firm can take two stylized forms, being characterized, alternatively, by shareholder (S) financial governance (Fs) or by debt-based (B) financial governance (Fb) where bondholders influence the strategic decisions of the firm and, in particular the ratio h between general purpose and specific capital.⁸ Let $z > 0$ be the economic return generated by the employment of general-purpose assets, and $Z > 0$ the economic return associated to specific assets⁹ with $z < Z$. Let us further define as p the probability of ‘success’ of the firm’s investments. Shareholders receive the full return pZ on specific assets in case of success, while, in case of bankruptcy (occurring with probability $1-p$), they only get a residual truncated¹⁰ amount z^S on general assets k (we assume that specific assets K are completely lost in case of bankruptcy), once the claims of the bondholders have been early satisfied. By contrast, bondholders get, in case of success of the firm’s investments, the truncated return z on both general-purpose and specific assets (i. e. bondholders do not get any extra-reward for risks due to specificity). However, in case of bankruptcy, they will get an amount z^B greater than z^S (again only on the general assets k). Summing up, the following ordering applies: $0 \leq z^S < z^B \leq z < Z$.

Denoting now by $c(k)$ and $C(K)$ the costs, respectively, of general-purpose and specific assets. Under shareholders’ control, the value V_s of shareholders’ expected returns is:

$$(1) \quad V_s = p(zk + ZK) + (1-p)z^S k - [c(k) + C(K)]$$

Under bondholders’ control, the value V_B of bondholders expected returns is:

⁷ In this particular respect, concerning the choice of the appropriate level of asset specificity, we assume that there are no agency costs between production managers and the individuals financing the firm.

⁸ In this simple setting we neglect internal funds raised by cash flows self-financing as a third way of financing investments, beside debt and equity. Worthington (1995) compares the trade-off between debt and cash flows financing instead of debt and equity.

⁹ All these variables are expressed in monetary units.

¹⁰ With limited liability this amount is always greater than zero.

$$(2) \quad V_B = pz(k + K) + (1-p)z^B k - [c(k) + C(K)]$$

In order to simplify the analysis, let us assume that shareholders get nothing in case bankruptcy ($z^S = 0$) and that, in the bankruptcy event, bondholders are able to get the same return, thanks to the priority of their claims, that they would get in case of success of the firm ($z^B = z$).

In this simplified form, equations (1) and (2) could be re-written as:

$$(1') \quad V_S = p(zk + ZK) - [c(k) + C(K)]$$

$$(2') \quad V_B = pz(k + K) + (1-p)zk - [c(k) + C(K)]$$

We assume now that managers choose, in the technological domain (T), the values of K and k on the basis of a given financial structure and that, in the financial domain (F), financial market intermediaries choose, the bond-holder or equity-holder profile of the firm on the basis of the generic/specific capital ratio h^{11} .

In the financial domain, market financial intermediaries will select the financial structure $\max(V_S, V_B)$ under which the expected returns of the firm V have the greatest value, given the technology chosen by production managers. The following proposition outlines the relationship between the choices made by market intermediaries in the financial domain (F) and the technology chosen by production managers in the technological domain (T).

¹¹ In the above framework we have explicitly excluded self-financing by internally raised funds as an alternative way to structure investment decisions. As Allen and Gale (2000) show, self-financing is one of the most diffused ways of investment financing among firms through different corporate governance systems. In our framework, self-financing could however be introduced as a particular case of equity financing. In this case, internally raised funds can be treated as a particular form of equity which gives no claims in the case of bankruptcy and which is selected when the degree of asset re-deployability prevents any debt contract. If this assumption is accepted, the results of our model still apply to self-financing.

Proposition 1.

In the financial domain F , the incremental benefit of having the scheme F_s of financial governance, instead of F_b , increases if, in the domain T , a more specific technology T_s is chosen instead of a more general purpose technology T_g . That is:

$$V(F_s, T_s) - V(F_b, T_s) \geq V(F_s, T_g) - V(F_b, T_g).$$

Proof. Given the existing technology (K, k) , and the range of values (z, Z) in the financial domain, intermediaries will choose the equity financing scheme F_s when $V_S \geq V_B$, that is when

$$p(Z-z) K_s \geq (1-p) z k_s$$

or

$$(3) \quad \frac{p(Z-z)}{(1-p)z} \geq h$$

.

Otherwise, the debt-financing scheme F_b will prevail. Recall that $h=k/K$ is the ratio between the generic and the specific capital of the firm. When firm's assets are highly specific, the value of h will eventually approach to zero and this will in turn increase the set of values of the ratio $\frac{p(Z-z)}{(1-p)z}$ that are higher than k/K , bringing to a F_s governance arrangement. On the contrary, when firm's assets are highly generic, the value of h will eventually approach to infinity and this will increase the set of values of the ratio $\frac{p(Z-z)}{(1-p)z}$ that are lower than k/K and will select a F_b equilibrium. In any case, the comparative advantage of a scheme F_s relatively to F_b will increase (or its comparative disadvantage will decrease) when h decreases from infinity to zero; namely, when the relative amount of specific assets rises and general purpose ones are reduced.

■

Proposition 1 shows how technologies with different degree of asset specificity, T_s and T_g , affect the marginal advantage of one kind of financing over the other (F_s over F_b) and, therefore, how the

choices done by production managers in the technology domain T affect the financial choices in the domain F .

Let us now turn to investigate the opposite direction of causality, i.e. how the choices made by market financial intermediaries, in the domain F , affect the technologies that are chosen in the domain T . We assume that there are no agency costs and production managers will maximize the utility of shareholders U_S if the firm is controlled by them and the utility of bondholders if the firm is under their control. Because of (1') and (2') we can therefore assume that managers will maximize:

$$(1'') \quad U_S = p(zk + ZK) - [c(k) + C(K)]$$

when the firm is under shareholder control

$$(2'') \quad U_B = pz(k + K) + (1-p)zk - [c(k) + C(K)]$$

when the firm is under bondholder control.

We can now state the following proposition (2) that clarifies the relationship between the technologies chosen by managers in the domain (T), given the control rights arranged by market financial intermediaries in the domain (F).

Proposition 2.

In the technological domain T , the additional benefit of having a more general purpose technology Tg (with respect to a more specific technology Ts) increases when debt governance Fb (instead of equity governance Fs) is chosen in the domain F . That is:

$$U(Tg, Fb) - U(Ts, Fb) \geq U(Tg, Fs) - U(Ts, Fs).$$

Proof. Given the financial governance systems Fs and Fb , the degree of assets specificity will be chosen maximizing equation(1') with respect to k and equation (2') with respect to K .

Under equity governance Fs , we thus obtain:

$$(4) \quad \frac{\partial U_S}{\partial K} = pz - C'(K) = 0$$

$$(5) \quad \frac{\partial U_S}{\partial k} = pz - c'(k) = 0$$

Under the debt-holder scheme Fb , we have:

$$(6) \quad \frac{\partial U_B}{\partial K} = pz - C'(K) = 0$$

$$(7) \quad \frac{\partial U_B}{\partial k} = pz + (1 - p)z - c'(k) = 0$$

Now, let us define by K_S and k_S as the argmax of U_S and by K_B and k_B the argmax of U_B . Since $Z \geq z$, from (4) and (6) we have that:

$$(8) \quad K_S \geq K_B.$$

Furthermore, since $(1-p)z \geq 0$, comparing (5) and (7) we have that:

$$(9) \quad k_B \geq k_S.$$

Therefore, from (8) and (9), it follows that:

$$(10) \quad \frac{k_B}{K_B} \geq \frac{k_S}{K_S}.$$

Thus, under a bondholders financial scheme Fb production managers will tend to choose technologies Tg with a higher k/K ratio than Ts that they choose under a shareholder financial scheme Fs . ■

Proposition 1 and 2, jointly considered, show a two-way relation between financial and technological domains. When shareholders financing Fs and a specific technology Ts are institutional complements, and/or when debt-holders financing Fb and general-purpose technology Tg are institutional complements, then multiple financial equilibria may emerge.

Propositions 1 and 2 involve the choices made in the two domains satisfy the standard super-modularity conditions.¹² These conditions are concerned with the property of incremental differences with respect to change in parameter value. They do not exclude the possibility that the level of the payoff of one choice is strictly higher than that of the other for the agent of one domain (or of both domains) regardless of the choice in the other domain. Thus, a unique equilibrium is possible. However, under certain conditions, there can be two pure Nash equilibria (institutional arrangements) for the system. When such multiple equilibria are possible, they define two different institutional complements (Aoki, 2001). The focus of the following analysis is to specify the precise conditions under which finance and technology choices involve two different complementary arrangements between these two domains. In other words, we wish to state the conditions under which a multiplicity of financial-technological organizational equilibria occurs and (Fs, Ts) and (Fb, Tg) are institutional complements.

A shareholder financial-technological equilibrium (Fs, Ts) is defined by the set of values for which shareholders financing Fs brings about the highest value of the firm given a technology Ts and, in turn, a technology Ts maximizes firm profits under the shareholders financing Fs . This occurs when the values of the arguments (ks, Ks) , that maximize (1''), satisfy:

$$(11) \quad p(Z-z) K_s \geq (1-p) z k_s$$

or, in other words at the values of (ks, Ks) , chosen under share-holders governance, the expected extra-returns of specific investments exceed the returns from general purpose investments that would be realized with probability $(1-p)$ by debt holders even in case of bankruptcy.

(11) can be re-written as:

$$(12) \quad \frac{p(Z-z)}{(1-p)z} \geq \frac{k_s}{K_s}$$

¹² See Milgrom and Roberts (1990), Topkis (1998) and Aoki (2001).

A *debt-holder financial-technological equilibrium* (Fb, Tg) is defined by the set of values for which debt-holders financing Fb brings about the highest value of the firm given a technology Tg and, in turn, a technology Tg maximizes firm profits under Fb . This occurs when (11) is not satisfied and the values of the arguments (k_B, K_B) that maximize (2) satisfy:

$$(13) \quad \frac{k_B}{K_B} \geq \frac{p(Z - z)}{(1 - p)z}$$

Denote now by

$$ER_{GS} = \frac{p(Z - z)}{(1 - p)z}$$

the ratio between the firm's expected extra-return coming from specific investment K and the expected return coming from general purpose investments k in case of bankruptcy.

The ratio k_S/K_S represents the asset specificity ratio relative to values of k and K associated to the higher specific technology T_S operated by shareholders, whereas k_B/K_B are the relative values of k and K associated to the higher general purpose technology T_g that is operated by the debt holders.

Because of (10), ER_{GS} must either fall within the range of values defined by k_S/K_S and k_B/K_B or in the range defined by 0 and k_S/K_S or in that defined by k_B/K_B and infinity. Thus we have the following proposition specifying the conditions for existence of multiple financial-technological equilibria as well as for a unique equilibrium.

Proposition 3. Multiple financial-technological organizational equilibria (F_S, T_S) and (Fb, Tg) exist when ER_{GS} falls between the values k_S/K_S and k_B/K_B . A unique debt-holder equilibrium (Fb, Tg) exists when ER_{GS} is smaller than k_S/K_S , while a unique shareholder (F_S, T_S) equilibrium exists when ER_{GS} is greater than k_B/K_B .

Proof. When

$$(14) \quad \frac{k_S}{K_S} \leq \frac{p(Z - z)}{(1 - p)z} \leq \frac{k_B}{K_B}$$

both (12) and (13) are satisfied.

When

$$(15) \quad \frac{k_S}{K_S} \leq \frac{k_B}{K_B} < \frac{p(Z - z)}{(1 - p)z}$$

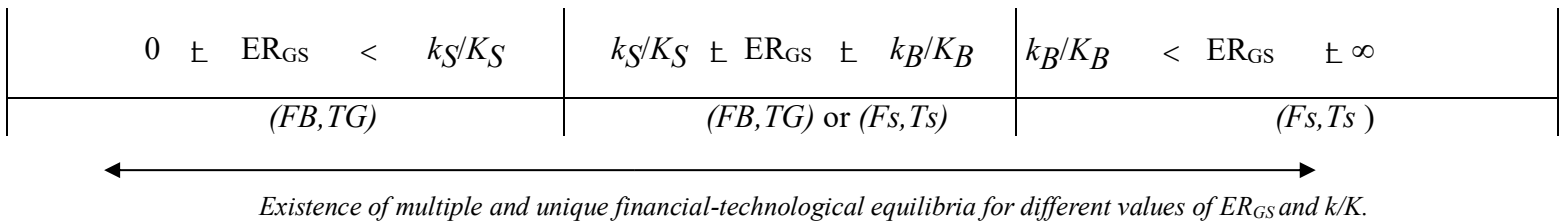
then (12) is satisfied but (13) is not.

When

$$(16) \quad \frac{p(Z - z)}{(1 - p)z} < \frac{k_S}{K_S} \leq \frac{k_B}{K_B}$$

then (12) is not satisfied whereas (13) it is.

Propositions 3 can be visualized by the following figure.



Proposition (3) has an interesting intuitive interpretation. *When the probability of success for the project (in terms of the non-bankruptcy event) is low and the ratio between the return of specific and the return of general capital is also low (that is ER_{GS} is low), then only debt-holders financial-technological organizational equilibria are possible. By contrast, when the probability of success is high and the ratio between the return of specific and general capital is also high (that is ER_{GS} is high), then only share-holders financial-technological equilibria are possible. For intermediate values of ER_{GS} , multiple self-enforcing financial-technological organizational equilibria will exist. Initial conditions affect the selection of the institutional complements (Fs, Ts) and (Fb, Tg) , defining the two possible different organizational equilibria.*

The existence of multiple organizational equilibria for intermediate values of parameters implies that initial conditions on financial markets and on the technological structure of the firm can shape

future decisions concerning the institutional setting of the two domains¹³. In these cases, path-dependency can have an important role in the evolution of the relation between technology and financial structures. Shocks on financial markets and/or on the technological structure of the firm can shape future (inefficient) decisions concerning the institutional setting of the two domains.

‘Shocks’, altering the relative comparative advantage of a financial choice and/or of a technical choice, could also be the result of regulatory reforms affecting one domain or the other. The regulation design adopted on the financial domain will affect managers’ incentives on the technological side. By regulating the characteristics and the boundaries of governance systems, one influences also the nature of the resources that are going to prevail in the economy. The latter are (at least partially) endogenously determined by financial structures and cannot provide a natural environment for their efficient selection.

4. Conclusion

Williamson’s (1988) has correctly emphasized that the degree of asset-specificity (or to use a Keynesian term, of (il)liquidity) involves that there is a dividing line among investments to be financed under equity and debt governance. According to Williamson super-governance system (dequity) could, in principle, provide an automatic and efficient divide between debt and equity governance. However, as also Williamson observes, this financial super-governance system does not exist and we are bound to live with a multiplicity of financial governance systems. In our paper we have provided a rationale for this multiplicity of organizational equilibria: technology is never chosen efficiently in a (super-)governance vacuum but it is always selected within a given governance system. For this reason, both equity and debt governances tend to bring about the complementary technology, which tend in turn to select the complementary forms of governance. Complementarities involve the possibility of multiple, and possibly inefficient, financial-

¹³ In this simple setting we neglect internal funds raised by cash flows self-financing as a third way of financing investments, beside debt and equity. Worthington (1995) compares the trade-off between debt and cash flows financing instead of debt and equity.

technological organizational equilibria and can explain both the diversity within and between different national systems.

Our analysis involves that the equity-debt mix may be inefficient because pre-existing governance systems may rule investment projects that may be more appropriately run by alternative systems. In particular (especially when represented by managers which are paid according to the returns of their capital but do not suffer the consequences of bankruptcy) bankers may go well beyond the optimal degree of specificity-risk compatible with lending and regulations may be necessary to align their interest with those of bondholders. In this respect, the suggestion that all regulations, (such the Glass-Steagall act that limited banks to investments in equities) should be abolished does not seem justified. For the safety of their depositors, it is desirable that bankers expand their credit in proportion to the size of re-deployable assets. However all shareholders have an incentive to invest excessively in risky assets and also bank's shareholders may be tempted to follow the same strategy. They may lend at high rates of interests to borrowers investing in excessively specific assets or they may even directly invest in risky equities (Mayer 2013). For this reason, it is necessary to have regulations, setting limits to the types of business in which banks can be involved. Ignoring the complementarities existing within the financial sector as well as between the financial sector and other sectors has been an important cause of the 2008 crash (Campbell 2011, Pagano 2014).

Financial-technological organizational equilibria can be interpreted as a way in which financial standards affect technological standards and vice-versa. Network externalities may imply that any pressure to standardize finance will lead to a standardization of technology and vice-versa. Even if we can ideally assert that one of the corporate governance models is characterized by some absolute advantage, this does not mean that a particular model, such as an ideal debt-equity system, should necessarily prevail over the others in the global market. Given the immobility of many factors, what matters is not the absolute advantage of particular governance system but its comparative institutional advantage (Hall and Soskice 2001, Bowles and Pagano 2006, Belloc and Pagano 2012). In our framework different financial-technological equilibria imply different relative costs of using specific and general-purpose factors. Thus, countries, characterized by different financial systems, may enjoy an institutional comparative advantage in particular production sectors (Svaleryd, Vlachos 2005). Suppose that a country is not open to international trade. In this case, even if network externalities, path dependency and other factors favor a particular type of financial structure, the high number of different sectors, necessary to have in a closed economy, involves

some diversity of corporate governance systems. However, suppose now that the economy of the same country becomes increasingly globalized. While globalization may put some pressure to standardize financial systems, its economy could now specialize in those sectors where, because of the characteristics of its financial system, it enjoys a comparative advantage¹⁴. Thus, if a country is in a particular financial-technological organizational equilibrium, globalization is not necessarily going to upset this equilibrium. In some cases, increased economic integration may even induce the opposite effect: the country may turn out completely dominated by its prevailing financial system and specialize in those sectors where such a system entails a comparative institutional advantage. Which outcome will prevail is an empirical issue requiring an extension of the analysis to other complementarities that characterize economic systems.

Financial-technological complementarities are only one of the numerous structural interdependencies characterizing economic systems. Other complementarities have been the object of other papers. The complementarities between property rights and technical assets can generate different organizational equilibria, one where labor hires capital and one where capital hires labor (Pagano 1993, Pagano and Rowthorn 1994). Similarly, banking and strong insiders control as well as shareholders and weak insiders' power, are likely to be institutional complements (Aoki 1994). Intellectual property and human capital investments complementarities may cause economic systems to enjoy virtuous high skill – rich IPR equilibria or to suffer vicious low skill - poor IPR equilibria (Pagano and Rossi 2004). The exploitative or liberal nature of the property right appropriation by the firms interacts with the innovative effort of the single employees (Gurpinar 2013). The low and high level of modularity in the software industry is complementary to the open and closed source property rights arrangements which characterizes the this industry (Landini 2012). Local financial development is complementary to the growth of cooperatives (Gagliardi 2009). Complementarities arising between the degree of capitalist concentration and workers' interests concentration have been the object of Belloc and Pagano (2009, 2013) and Milhaut and Pistor (2008). The literature on the varieties of capitalism has explored numerous and fascinating complementarities existing in each system of regulations and of corporate governance (Boyer 2005, Amable 2003, Amable, Palombarini 2005, Aguilera, Jackson 2003 and 2010). Finally (but the list

¹⁴ The comparative advantage may arise also because of different institutions (Hall and Soskice 2001 and Bowles and Pagano 2006) or may be even "forced" by different endowments of Intellectual Property Rights (Belloc, Pagano 2012).

is necessarily incomplete), Aoki (2010), has explored the institutional complementarities among societal rules, polity domain and corporate governance.

The goal of our paper has been to fit some more pieces in the complex complementarities puzzle characterizing different economic systems. Further research is required to find the other missing pieces and to make them all fit together in a general framework. One should also rely on some form of “meta institutional complementarities”, making the whole puzzles less disconnected by bridging together the institutional complementarities examined by the literature. From partial solutions to numerous institutional puzzles, an impressionistic and still much stylized painting of whole systems is starting to emerge. When a broad panoramic picture will be better defined, we will also have a better understanding of the parts on which we have already tried to focus our lenses, including the financial and technological complementarities examined in this paper.

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