Systems Approach in Social Sciences

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Abstract

On an example of two hotly discussed concepts of social capital and proximity we demonstrate usefulness of systems approach in social sciences. The paper is self-contained and dos not require any previous grounding in systems analysis. In the first part of the paper, we give a short description of main relevant techniques used in systems analysis.

The main objective of our work is to provide the methodology for an assessment of the value of social capital of a firm broadly viewed as a profit or non-profit organization. Next we use our methodology in evaluation of the utility/value/volume of a given proximity and demonstrate that these two concepts are very relevant. We describe two models, introduced by Walukiewicz, for an analysis of both social capital and proximity: the accounting model (part two) and Virtual Production Line (VPL) as the managerial model (part three). The paper contains the main results of such analysis as well as examples of using VPL in analysis of social capital and proximity in different sectors (part four).

In conclusion, we present generalizations and outline some future works on the analysis of social capital and proximity.

Key words: Systems approach, social capital, proximity, value/volume/utility of social capital/proximity.

1 Introduction

The main objective of this paper is to demonstrate how systems approach can contribute to better understanding two concepts: social capital and proximity. The first is among the most hotly discussed concepts in social sciences these days, ranking as high in importance as economics, management, sociology or political sciences, and we will demonstrate that the second is very relevant to the first, and, moreover, the concept of proximity is useful in analysis of such complex notion as social capital.

The number of publications on social capital is growing rapidly. In 2000 – 2005, more than 2,000 papers pertaining to this issue area were published and filed in ProQuest, SocioFile and SocioINDEX databases. The World Bank and other leading economic institutions, or even individual scientists, have developed websites to collect and disseminate relevant information. Despite massive popularity however, until now, no standard definition of social capital has been clearly coined. More than that, many authors, e.g. Arrow [1] and Solow [2] and Sobel [3], to name a few, find it misleading, confusing or a bad metaphor. See Powar [4] and Quibria [5] for the most recent and detailed analysis of what meanings arose around the notion of social capital. Below, we claim that a lot of definitional questions and confusions related to the matter at hand are tightly connected with the problem of how to evaluate, asses and measure social capital of a given firm, region or country, either it in volume or value terms.

The concept of proximity was introduced and developed by the French proximity school (Torre and Gilly [6], Torre and Rallet [7], Torre [8], Rallet and Torre [9] and more recently studied by Menzel [10]). We introduce a concept of Virtual Production Line (VPL) as a managerial model for social capital analysis and show how VPL can be used in proximity studies (see also Walukiewicz [11] and [12]).

The paper is self-contained and does not require any previous grounding in systems approach. In Section 2 we provide a compact description of the main techniques of systems analysis, illustrated by examples from economics and management. For better presentation of our reasoning we use figures, mathematical formulae and charts. We introduce the concept of orthogonality (independence) of inputs or (explanatory) variables and demonstrate how important it is in social sciences, in particular, in analysis of both social capital and proximity.

We introduce a firm *F*, by which we understand any profit or non-profit organization, where people (workers, partners, etc.) combine their efforts to achieve its more or less clearly defined objectives and whose strivings can be measured with certain accounting systems. Our firm *F* can be an industrial/service company, research/consulting institution, university/school, sports club, professional/political organization, etc. We show in Section 3 that the term "social capital" is correct and not misleading. We argue that it is one of four possible forms which make up the entire capital of firm *F* and should be measured in monetary units, as three other forms, financial, physical and human are.

In Section 3 (see also Walukiewicz [11] and [12]) we introduce the accounting model for social capital analysis and demonstrate that the partition the entire capital of *F* into the four categories above leads to new, interesting results and contributes to better understanding of the concept of social capital. Next, in Section 4, using the concept of VPL we demonstrate that there are four forms of proximity, mutually disjoint or orthogonal to each other and give some examples of applications of VPL. Therefore proximity, like capital, is a four-dimensional concept. We extrapolate our findings to the regional/national level and formulate suggestions for further research in final conclusions.

2 Systems approach

Researchers always work with models of reality, not with reality as such. The main doubt is then how confident one may be that the model at hand is relevant enough. How useful it is in scientific studies on reality? Modeling, or building models for scientific research, is in common belief an act of art and is governed by a few general principles. The main principle says that it is a stepwise exercise in which one begins with a general model, vaguely addressing the piece of reality concerned, and then comes up with more adequate and precise models as they proceed to more advanced stages. Below we describe systems approach techniques applicable in such modeling. In the following Sections we present two models for analysis of social capital and proximity.

2.1 Main techniques

Input-output analysis is a key technique used in systems research whereby a piece of reality (in the case hereof, a firm or region/country) is modelled as a **relatively closed system** with inputs *x* and outputs *y*, relations of which are investigated (see Fig. 1). The system is called relatively closed because we assume at one point that it interacts with its surroundings, that is to say the rest of the world, only through its specified inputs and outputs. We may choose to increase the number of inputs/outputs as well as change their specifications down the road. Anyway, we will always keep in mind the well known (systems approach) principle: from the general to particular. The main question of systems approach lies in relations between the inputs and outputs or, to put it otherwise, how the system in hand transforms its inputs into outputs? The answer is twofold:

i) **Function *f*.** We look out for **function *f***, if possible expressed by a mathematical formula, such that $y = f(x)$. Below we consider two examples of such an approach.

ii) **Subsystems.** We define a **system** as a finite set of constituent elements called **subsystems,** interacting to achieve a supreme goal of the system concerned. In this approach we look to identify subsystems filling the box on Fig. 1 and find out how they interact in the transformation of inputs coming up into outgoing outputs. We will look in detail at this approach in Section 5.

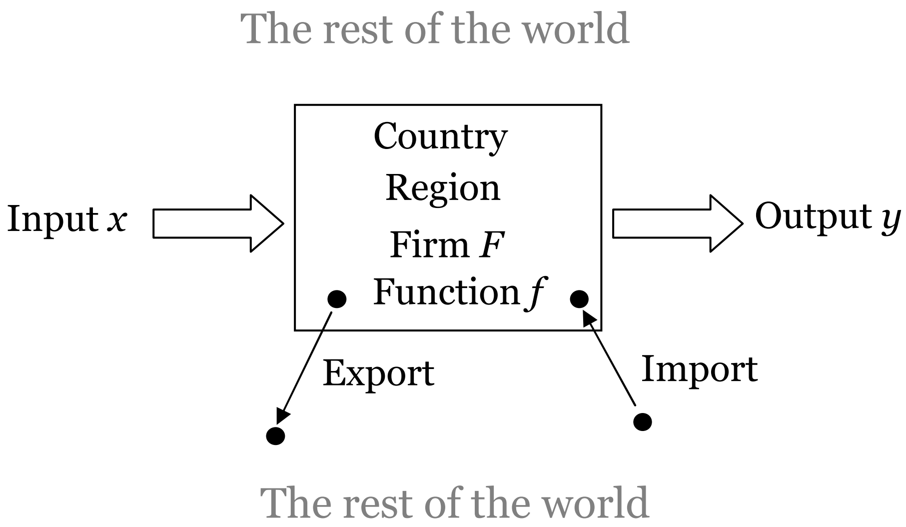

Fig. 1 Economy at different levels as a system

Example 2A Think of the national or regional economy as a system with three inputs: labor *L*, capital *C* and technology *T*, and *GDP* (gross domestic product) as its output. Using the Cobb-Douglas production function *f* (see e.g. Sachs and Larrain [13], p. 430 for details) we may approximate the value of *GDP* in monetary units as a function of the number of workers *L*, the value of capital C and the production technology coefficient *T*, $0<T<1$, namely

$$GDP = f(L,C,T) = L^{T} C^{1-T}\,. \qquad (1)$$

This is an example of a multiplicative function, often used in econometric models.

Example 2B In the expenditure approach to *GDP*, its monetary value (for details see Parkin [14], p. 498), depends on four input variables: personal consumption expenditure x_1 , gross private domestic investment x_2, government purchase of goods and services x_3 and net exports of goods and services x_4, namely

$$GDP = f(x_1, x_2, x_3, x_4) = x_1 + x_2 + x_3 + x_4. \quad (2)$$

We note that the net exports represent an interaction of the closed system (national economy) with the rest of the world and may be positive or negative, as

$$x_4 = \textit{value of gross exports} - \textit{value of gross imports}.$$

In (2) the function *f* is additive, as always is in accounting modes. Even though in export or import relations one actor is located elsewhere in the rest of the world, i.e. outside the considered closed system, we always count the output of such a relationship, i.e. its positive or negative result, as relevant to the system under consideration.

2.2 The orthogonality of inputs

In the above examples, the inputs are multidimensional, in Example 2A – 3-dimensional and in Example 2B- 4-dimensional, while the output is a scalar (1-dimensional variable). Such a situation is very typical in systems approach. We observe that these inputs are orthogonal (perpendicular) to each other or they are mutually disjoint as they describe reality along directions (axes), which are orthogonal to each other. It can be easily seen in Example 2A, as nobody will mix people (labour *L*) with money (capital *C*) or technology *T*. Things are much more complex in Example 2B, but orthogonality of inputs or the fact that they are mutually disjoint is manifested in that GDP is calculated against the accounting model (balance sheets), where every item is taken into account once and only once in computing $x_1, \ldots, x_4$.

To demonstrate the importance of the orthogonality of inputs we consider the following other example:

Example 2C In Fig.2 we present the results of a hypothetical presidential election forecast. There are two candidates, denoted on axis x_1 as A and B. Let the poll results be that: 42 ± 3% for the candidate A and 48 ± 3% for B, with 10% undecided. The results along x_1 are given with zero error (tolerance), that is they are as precise as possible, while along x_2 a certain amount of error is allowed which cannot be reduced to zero because the poll represents voting preferences of a small portion of all potential voters, even though selected in a scientific-based way. Besides, some of them can change their mind before the election gets under way or lie for one reason or another. We note that decreasing the amount of error, say from ±3% to ±2% will, in general, require a lot of investment in terms of effort, money and time. We conclude that in social sciences some variables are always measured with some nonzero error (tolerance).

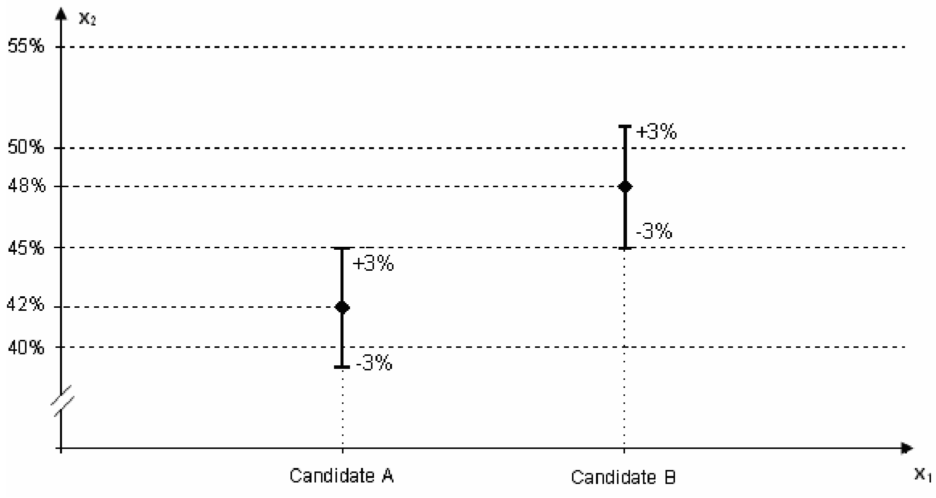

Fig. 2 Election results forecast

Let us assume for a while that measurable concepts in social sciences, such as social capital are described by two criteria (variables) x_1 and x_2, measured with tolerance dx_1 and dx_2, respectively. If these criteria are independent or disjoint, as illustrated by the orthogonality of the corresponding axes x_1 and x_2, then the concept we are interested in may be represented in Fig.2 as point X or Y, within the rectangle ABCD, but not point Z because it is outside this rectangle. As our knowledge about the concept increases, then the tolerances dx_1 and/or dx_2 shrink and our rectangle will grow smaller. Ultimately, it will become a point, which will mean that we have arrived at the precise definition of what we investigate.

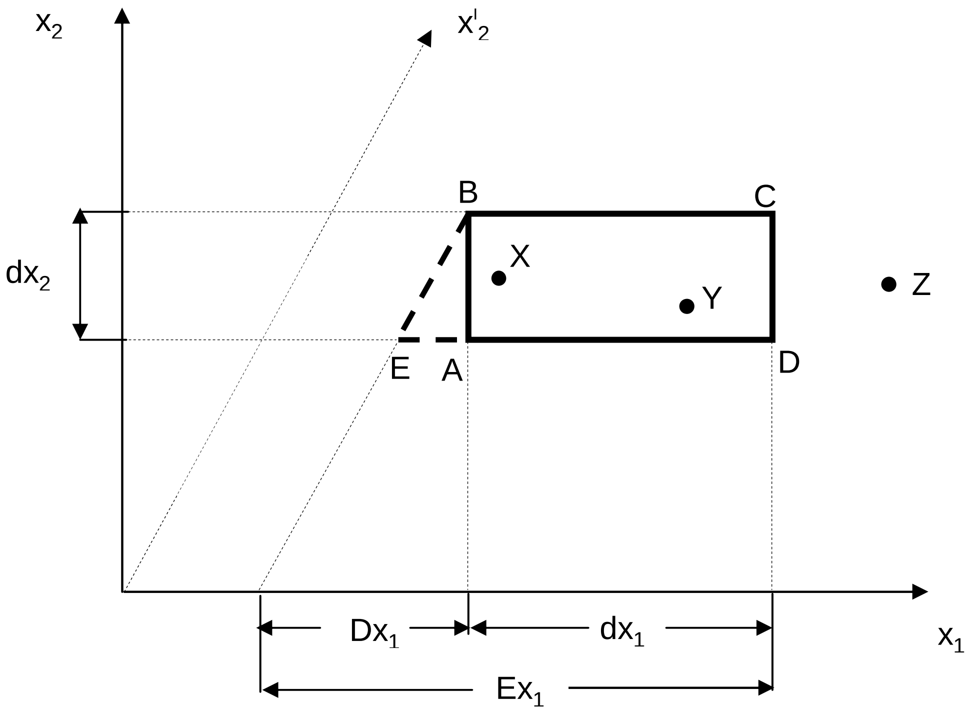

Fig. 3 The concept in social sciences described by two criteria x_1 and x_2

What happens if the criteria are dependent, not disjoint or the corresponding axes are not orthogonal? In Fig. 3 the new axis x'_2 is denoted by the doted line and the angle is now strictly less than 90^o. Then the concept at hand is located somewhere in the trapezium EBCD and, more importantly, the dependence of criteria induce an extra error Dx_1 (see Fig. 3). Now, the total amount of error along x_1 is bigger and equals $Ex_1 = dx_1 + Dx_1$. Similar things happen when the angle is obtuse and there are more than two criteria describing the concept. We may therefore formulate as follows:

Remark 1 The dependence of criteria (variables) induces extra errors.

Without orthogonality of inputs the research results (outputs) are burdened with additional errors, which makes analysis (statistical, cluster etc.) more difficult and conclusions much weaker. It happens when e.g. answering a questionnaire - we note that answers to, say, question 17 is relevant in connection with, say, question 10, already done. In Conclusions we make a recommendation how to avoid such pitfalls in the designing of questionnaires.

3 Social capital

The entire capital (all assets) of a typical firm (our firm *F*) is too complex to analyse it as one entity. Dividing it into two forms (parts), called **tangible assets** and **intangible assets**, is still too complex. On the other hand, we are not inclined to go into too much detail and, more importantly, we want the forms of capital to be disjoint, independent or orthogonal in the way it is construed in Section 2. Below we divide the entire capital of firm *F* into four forms (categories, parts, components), show that such a division is a new quality and a source of our new results. At the end of this Section we explain why the division of the entire capital into three forms is not interesting both from theoretical and practical point of view.

3.1 Indicative description of four forms of capital

Since firm *F* as profiled in the Introduction thereto is almost any organization, then the above four forms of its capital cannot be defined in a concise, scientific way. We prefer then to describe them in an indicative way, featuring the most important aspects of each. We hope that this indicative description can be applied in practice as well. The four forms in question are as follows:

1. **Financial capital (FC)**, made up of short–term and long–term finance (savings, loans, sale of stocks, sale of bonds, retained earnings etc.). Its value, denoted as *v(FC)*, can be calculated for any moment in the past and present as a sum of all components with a corresponding plus or minus sign and including a discount rate. Different currencies can be converted into a target currency in a standard way. Data for such calculations of *v(FC)* in the past and present are available, in general, in banking and accounting records of a given firm. Future value of financial capital can be calculated using techniques of short-term or long-term financial forecasting.

2. **Physical capital (PC)** comes in the form of buildings, machines, infrastructure, equipment, row materials, products, furniture, computers and software in its materialised form of license documents, etc., all collectively known as tangible property. For the purpose of this paper, we generally assume that the value of physical capital, denoted as *v(PC)*, can for any given moment in the past, present or future be calculated

or assessed in a reliable way using accounting and investment planning documents/statistics as well as amortization techniques.

3. **Human capital (HC)** is derived from competences, tacit knowledge, experiences, skills, education, training, etc. of workers considered as discrete individuals. The value of human capital of a firm, *v(HC),* is a subject of debate among practitioners and researchers (see e.g. Lin [15], Edvinsson [16], but until now, in contrast to the two above forms, there is no standardized, commonly accepted way of calculating or even estimating *v(HC)*. No doubt, *v(HC)* is closely related to compensation for the work done, its volume (time), intensity, quality, conditions etc. Education, training, experiences, etc. from the past and present are, in general, investment for the future. Edvinsson and Malone [17] suggest measuring *v(HC)* as a lump sum of compensation for all or specific work, e.g. of experts, in a firm throughout the employment time, including corresponding discount rate. This formula notwithstanding, we assume for the moment that we can somehow asses *v(HC)* for the past, present and future of firm *F* and will come back to this question by the end of this Section.

4. **Social capital (SC)**, which is composed of formal and/or informal relations among workers, teams, organizational units, etc. within a firm (**internal relations**), as well as formal/informal relations with customers, suppliers, banks, regional/central governments, R&D institutions etc. (**external relations**). All these relations set the stage for so-called organizational culture viewed as a pool of formal/informal rules, principles, behavioural standards, conduct procedures, etc. Clearly, such relations lie at the core of the study herein. We define each relation as a two argument function as it describes interactions (cooperation, joint actions, etc. – elements of **positive social capital** as related to the firm's objectives, but also arguments, personal fights, etc. – elements of **negative social capital**) between two actors (experts, team of specialists, members, etc.). The output (result) of such interactions at present depends largely on a history of a given relation in the past. Similarly, future interactions and new relations depend on the past and the present of them. This leads to the conclusion that the past, present and future value of social capital of a firm, *v(SC)* - and this is the primary subject of this paper - is the aggregate sum of values of all such relations. We assume for the moment that we know how to asses *v(SC)* for the past, present and future, and will come back to this question at the end of this Section.

The above division serves only as an illustration because it is extremely difficult to provide a definition of any form of the capital of a firm so generally defined as the one provided at the beginning of this paper. For the same reasons, we use 'etc' in the above definitions.

One can easily deduct from the above our social capital 'recipe.' We first slice the firm *F* assets into tangibles and intangibles. Since any account or banking product can be converted into real, touchable money, we consider all financial capital of firm *F* as tangible assets. Similarly, since for any legally bought software or patent we have or always could have a corresponding licence written on paper (a material thing), we count software and patents as elements of physical (material) capital of firm *F.* Among all tangibles we distinguish financial capital as elements of monetary (financial) nature and call the rest physical capital. As financial capital is measured in monetary units, so we measure physical capital in the same units using known amortization methods. Among all intangible assets we distinguish human capital as a resource associated with people (workers), considered as discrete human-beings, with their ability to think, cooperate with each other, express emotions, etc., and call the rest social capital. As human capital is closely related to the work of workers, measured in monetary units (see point 3. in the above definitions), then we would like to measure the value of social capital in the same units. But as this question is much more complex, we will often first have to asses the volume/value of social capital using points, rankings, etc., and then somehow convert them into monetary value *v(SC).*

From the above considerations one can easily conclude that tangible assets are disjoint from or orthogonal to intangible assets. Next, among tangible assets we, generally speaking, call financial capital anything that can be deposited on banking accounts of firm *F* and call the rest physical capital. Markedly, financial and physical capitals are disjoint or orthogonal to each other. As we go on, anything among intangible assets of firm *F* that is in the heads, hands and legs of workers viewed as discrete human beings would be human capital. The rest that is associated with internal relations of at least two workers of firm *F* would be called social capital. Interestingly, workers of firm *F* take their human capital home, while social capital is left at work. The latter is tightly connected with “the spirit of firm *F*”, both in positive (dedication, trust, honesty etc.) and negative sense (personal fights, distrust etc.) The external relations will be dealt with in this paper in exactly the same way as export and import in Example 2B (see also the next Subsection). So, human capital and social capital are disjoint or orthogonal.

We can therefore formulate as follows:

Lemma 1 Financial capital, physical capital, human capital and social capital of firm *F*, once viewed in the above indicative way, are mutually disjoint or orthogonal. The division of the entire capital of firm *F* into the above four forms is its **partition.**

A graphical representation of this statement given in Fig. 4 below

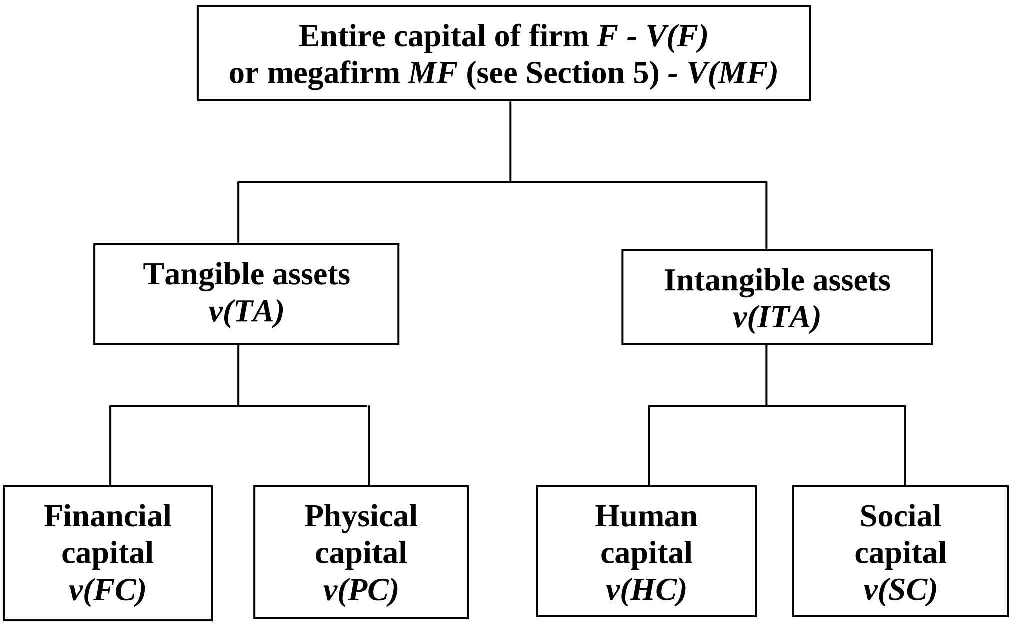

Fig. 4 The partition of the entire capital of firm *F* or megafirm *MF* (see Section 5)

While in Section 5 we continue to address the relations between the four forms of capital we will finish this Subsection with the following observation: presently there are 10-20 different categories of financial capital, though in point 1 of the definition herein only 5 are mentioned. Although their number is slowly growing, it is incomparable with practically uncountable number of different categories of physical capital. Similar finings are reached when human capital (6 categories mentioned in point 3 of the definition) is collated with social capital. In Section 4 we demonstrate that such practically uncountable diversity of social capital relations can be divided into four disjoint groups.

3.2 The accounting model

The value, and more general, the volume of any of the four forms of capital as defined above can be assessed or measured in one of two principal ways:

i) As a **stock** – a quantity that exists at a given moment of time *t*, for instance, *v(FC,t)* means the value of financial capital, measured in monetary units, at a given moment *t*, e.g. at the end of the year *t*.

ii) As a **flow** – a quantity per unit of time – we will denote it as *r(FC,t)* for financial capital per, say, one year *t* and define it as

$$r(FC,t) = \frac{v(FC,t) - v(FC,t-1)}{v(FC,t-1)} 100\%, \quad (3)$$

where *v(FC,t-1)* denotes the value of financial capital at the end of the previous year. So, in the above example, *r(FC,t)* defines the percentage increase or decrease of value of financial capital in year *t* against the value of financial capital in the previous year *t-1*. We will call *r(FC,t)* the **financial capital ratio for year *t***. In many textbooks on economics only the numerator, i.e. *v(FC,t)-v(FC,t-1)* of (3), is taken as the (absolute) measure of a flow under consideration, which is useless in comparisons. In this paper we will always measure flows using formulas similar to (3).

Obviously, these two quantities are related: if we know the stock of social capital at the end of year *t-1*, that is *v(FC,t-1)*, and we know the financial capital ratio for year *t* , that is *r(FC,t)*, then we can compute the stock of financial capital at the end of year *t*, namely

$$v(FC,t) = v(FC,t-1)(1 + \frac{r(FC,t)}{100\%}) \quad (4)$$

Similar considerations and notations are valid for the three remaining forms of capital. All these ratios are expressed in % and can be positive or negative.

By *V(F,t)* we will denote the value of firm *F* at time *t*. It can be established in two main ways: For firms listed at stock exchanges, *V(F,t)* equals the number of issued stocks times their stock price or (the second way), *V(F,t)* is established as a result of negotiations between the seller and the buyer (see Walukiewicz [12] for details).
Since the entire capital of firm *F* is partitioned into four forms (see Lemma 1), we can propose the following formula (5)

$$V(F,t) = v(FC,t) + v(PC,t) + v(HC,t) + v(SC,t) \quad (5)$$

for any moment *t* in the past, present or future of firm *F*.

We will call it **Fundamental Equation** as it forms a base of the **accounting model** for social capital analysis. The formula says that in market economy, under the equilibrium conditions, when demand equals supply, the value of a firm *F* equals the aggregate sum of four component values of its capital: financial, physical, human and social at any moment *t* of the firm's past, present and future. For instance, Fundamental Equation was not valid in the well known case of Enron, since than the equilibrium conditions were disturbed by crime. 'The past', 'present' and 'future' references vary by firm and sector. We will also call (5) the accounting model since we use accounting methods and techniques to calculate or asses the four values concerned. The Fundamental Equation also says that both the value of a firm and the four forms of its capital are **cumulative**, i.e. their values (stocks) are changing gradually in the past, present and future. Further on, we postulate as follows:

Lemma 2 In one-person company $v(SC) = 0$, i.e. there is no social capital.

It takes at least two experts, two staff members, two organizational units, etc. to build any relation in a firm, a basic element in evaluation of $v(SC)$. We observe that the **synergy effect**, the basic concept in management science, appears only when there is cooperation of at least two people, that is when $v(SC) > 0$. External relations of such one-person company should be taken into account in evaluation of its human capital, as exports and imports are considered in evaluation of GDP of a given country or region (see Section 2.). To sum it up, there is no social capital in one-person company, its intangible assets consist of only human capital and the value of its human capital is dependent on the size and amount of such external relations.

One-person company with its $v(SC) = 0$ plays the same role in economics and management science as temperature $0°C$ - the freezing point - in physics. So, we conclude that $v(SC) \geq 0$ at all times. Similarly, we hold that $v(HC) \geq 0$ (Walukiewicz [12]). The value of financial capital can be negative in case we have debts, loans, etc. The same can happen to the value of physical capital when, e.g., the cost of utilization of used machines, computers, etc. needs to be accounted for. Let $v(TA)$ be the value of tangible assets of a firm and $v(ITA)$ be the same for intangible assets. We conclude as follows:

Lemma 3

a) *Since* $v(HC) \geq 0$ *and* $v(SC) \geq 0$, *then* $v(ITA) = v(HC) + v\,(SC) \geq 0$.

b) *Since* $v(FC) \gtrless 0$ *and* $v(PC) \gtrless 0$, *then* $v(TA) = v(FC) + v(PC) \gtrless 0$.

3.3 Remarks

3.3.1 Decoupling. We will use the concept of one-person company in our analysis of social capital in multi-staff organizations such as universities, research institutes, etc., where professors, top experts etc. form, in fact, research units working as one-person companies. Specifically, in stage one of this analysis we will assume that a given university, research institute, consulting company etc. is a set of a particular number of one-person companies, each with a corresponding human capital and an aim to increase it as much as possible - though, at the end of the day, all contributing to the prestige, reputation, etc., of their parent institution, generating new projects, contracts, etc. (financial capital) and possible investment in physical capital. Such an approach is called in systems sciences **decoupling.** In the first stage of the analysis, then we will assume that the above relations are negligible, while in the next stages we will address them as a matter of primary importance. The question of what actually is important and when lies in the essence of systems analysis which is sometimes called the art of modelling.

3.3.2 Examples from sports. Relations between the above four forms of capital can even be better seen in a sports club. Take Manchester United, one of the richest football clubs in the world. Each of its top players represents best quality human capital (skills, experience, competence, etc.), sufficiently well defined in monetary terms during so-called transfer periods. Each player can be considered as a one-person company - though, in fact, he has a personal manager, lawyer and secretaries - with an objective to increase its human capital as much as possible. Thus we obtain data to estimate *v(HC,t)* of Manchester United for any *t* from the past and present. At training players try to increase their human capital even when they work out a collective action and a match is a comparison of social capitals of two competing teams at a given moment of time. To run more reliable comparisons, different rankings and statistics (regional, national, international, seasonal, historical, etc.) are held. If players do well together, then the social capital of the club is high in terms of value, with obvious implications for its financial and physical capital. And vice versa, one, single player can play brilliantly and his/her human capital may be the highest on the sport arena at a given *t*, but his/her team is losing out because the social capital of the competitor is higher. The history of team sports is full of relevant evidence. If the club is listed on a sock exchange, then we know its value *V(F,t)* for any past or present *t* and using (5) we can calculate its social capital value as

$v(SC,t) = V(F,t) – v(FC,t) – v(PC,t) – v(HC,t)$ for any *t* from the past and present of *F*.

3.3.3 Evaluation of human capital and social capital. We follow the principle: from the general to particular and note that both values of human and social capital are mostly made up by top experts, professors, specialists, etc., which we already observe above. For instance, *v(HC)* can be gauged by calculating the amount of compensation of top experts, professors, etc. Additionally, we may study indicators from so-called professional (academic) market, where human capital of experts, scientists, etc. could somehow be estimated, mostly in an indirect way (academic market knows who is strong and in what subject) or directly, by way of e.g. expert ranking lists. We observe now that top managers are changing jobs the way top sports players do.

In common belief, the market value of Microsoft is almost entirely defined by its 50 top experts (software engineers) or so. Therefore, in the first attempt to calculate the value of social capital of Microsoft, we evaluate relations between these experts only (for instance, what projects they participated in and how these projects contributed to the value of the firm in the past and present and how they will affect such value in future). So, instead of assessing all possible relations among 76,000 Microsoft workers, in the first step of our analysis we study such relations only between its 50 top experts. Finally, if we assume (see the above Remark) that the value gap is almost entirely covered by *v(HC)* and *v(SC)*, then we can calculate their values. To do it, we need to establish, e.g. by experts the relation between them (see Walukiewicz [12] for details).

3.3.4 Different frequencies. Consider once more the Fundamental Equation and observe that the values of its right hand side are changing, in general, at very different frequencies: Due to the modern computer banking systems we can register any change of *v(FC)* in seconds or even nanoseconds, but whatever the changes in the value of physical capital, they are registered only once a year because of used amortization techniques. Also contracts with top experts (human capital) are usually signed for years, and the projects are evaluated on the yearly basis (social capital). Therefore, in the application of the Fundamental Equation in a particular sector or company, using certain smoothing techniques, may be necessary.

3.3.5 Why four, not three? A question arises why not bind human and social capital together, call them intellectual capital, and then analyse three capital forms instead of four. There are three main reasons why not: first, the methodology we adopted leads to new interesting results as formulated in Lemmas 2 and 3 above; second, it has its own appeal and structure; third, it can be used to describe a managerial model for the analysis of social capital, which will be discussed in Section 4.

4 Proximity

To describe our next model for social capital analysis, we need general information about an assembly/production line, which we would like to explain with an example from the automotive industry.

4.1 Classical production line

Before 1915 cars were manufactured in so-called production circles (see Fig.5), where a few highly skilled craftsmen produced a car from beginning to end using parts and raw materials. The division of labour in such a production process was very flexible, in fact, craftsmen could easily substitute for one another, and the obvious limit for productivity was the number of highly skilled craftsmen.

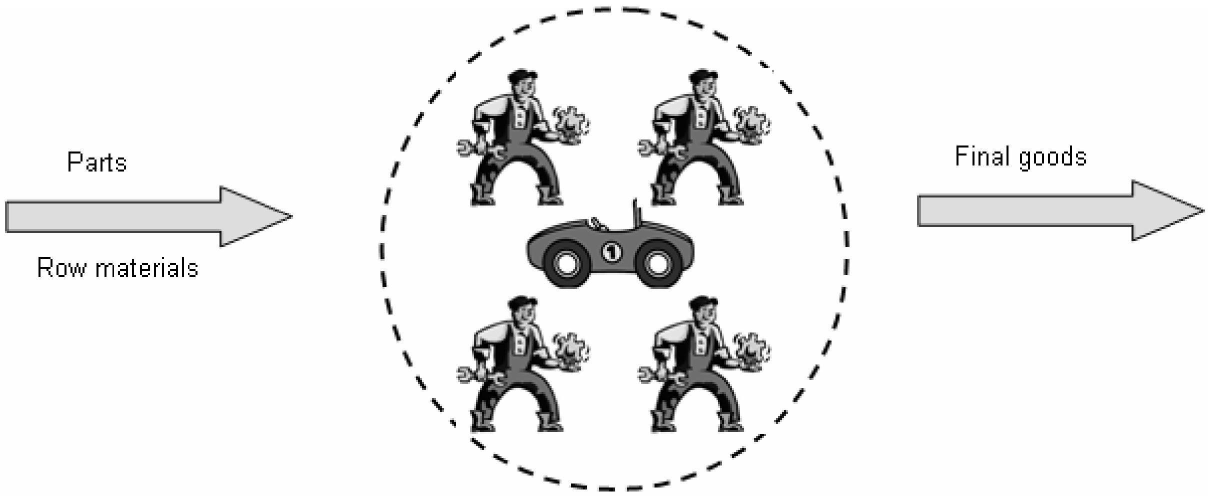

Fig. 5 Production circle

Henry Ford was the first who put into practice the following observation: if we partition a complex car manufacturing process into a fixed number of simple operations (jobs) done by simple workers (blue collars) on a line (belt) (see Fig.6), then its productivity will increase and the problem of limited number of highly skilled craftsmen should be solved. It is one of the greatest achievements in management science and economics. The idea of the assembly line was then applied in many production and service processes. If we have many production/service lines manned by people or robots, then for the purpose of our analysis, we join them into one production/service line, which we will call the **Classical Production/service Line (CPL).**

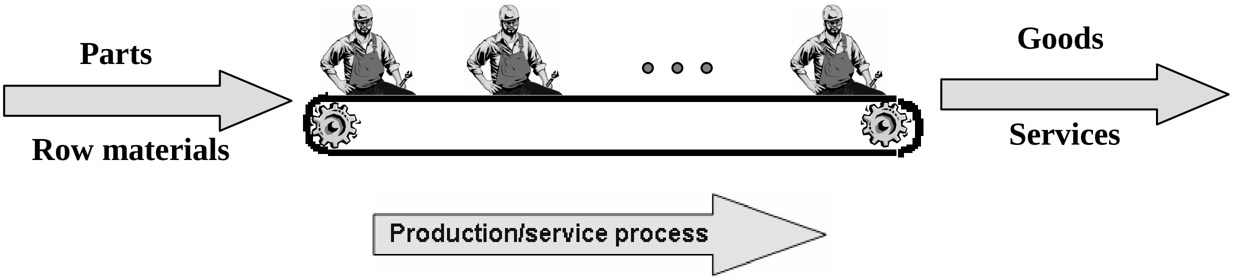

Fig. 6 Classical Production Line (CPL)

Let us assume that a given worker has increased his/her skills (his/her human capital) and now can do the job assigned in half the previous time. Does it have any impact on the organization/productivity of the considered production process? The answer is no. His/her extra skills may be used in the design and implementation of another production process on CPL, but not in the one in hand as its organization is fixed. We conclude that CPL does not allow of any **self-organization** and workers (blue collars) are to work on it, not to think.

Definition 1 Classical Production/service Line (CPL) is a partition of a complex production/service process into a fixed number of simple operations (jobs) described to the smallest detail. Such a partition is fixed for a time and does not allow of any **self-organization** (see Fig. 9).

4.2 The model – Virtual Production Line (VPL)

When an individual applies science, he/she does it either in their private interest or to increase the value of his/her human capital on an academic market, e.g. to obtain Ph.D., a certificate, etc. The situation drastically changes when a team of experts apply science, since it is then social capital that is involved in such a creative process and one may expect the synergy effect (Lemma 2). It is our contention that the team pools their efforts to solve a problem, however vague the problem appears to be at an initial stage. Therefore, we make the following

Main assumption Application of knowledge by teams of scientist, experts, specialists, etc. is always connected with solving a problem. It may not be well-defined or be described in a fuzzy way, but always has a creative, problem-solving nature.

Let us consider a **Virtual Production Line (VPL),** pictured in Fig. 7, where there are a number of experts (teams of experts), scientists, specialists, etc. with their laptops, computers, data bases, etc. (in Fig. 7 we show their keypads and monitors), connected via the Internet or any ICT networks, solving a given more or less accurately defined problem of our firm *F* during a creative process. Since there is no material representation of the VPL (our experts can be located in different parts of the world), we denoted it in Fig. 7 using a doted line.

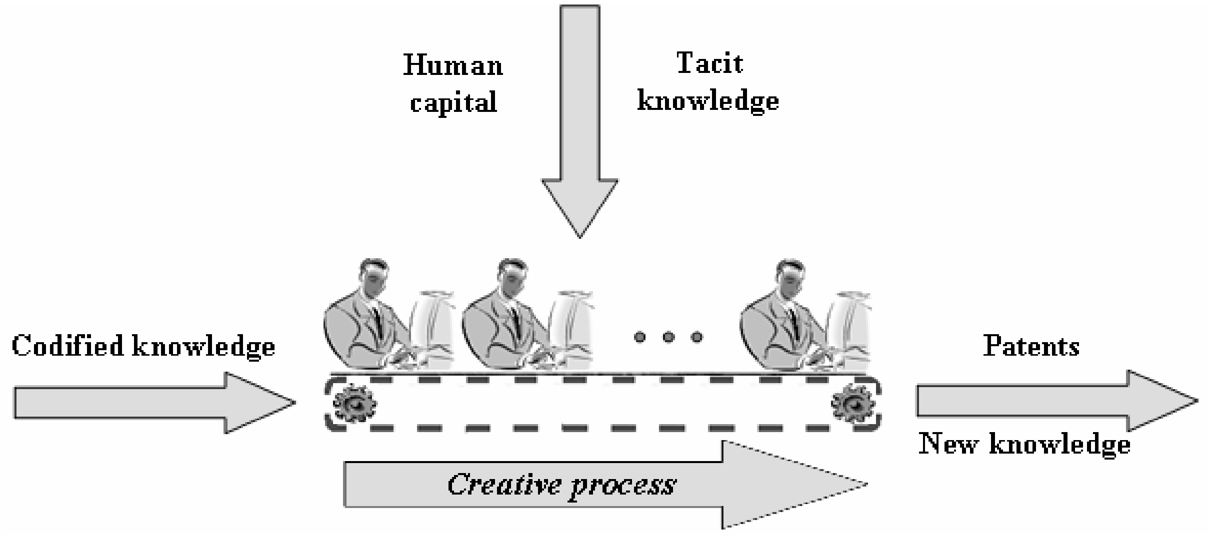

Fig. 7 The concept of Virtual Production Line (VPL)

The experts combine their human capital, mostly their tacit knowledge with the codified knowledge to solve in a creative process a problem which may have at the beginning not been well defined or described in a murky way, but which, due to their efforts (**self organization**), is getting more and more clear-cut and distinctive. In other words, experts on VPL not only work, but also think. See Fig. 8 below.

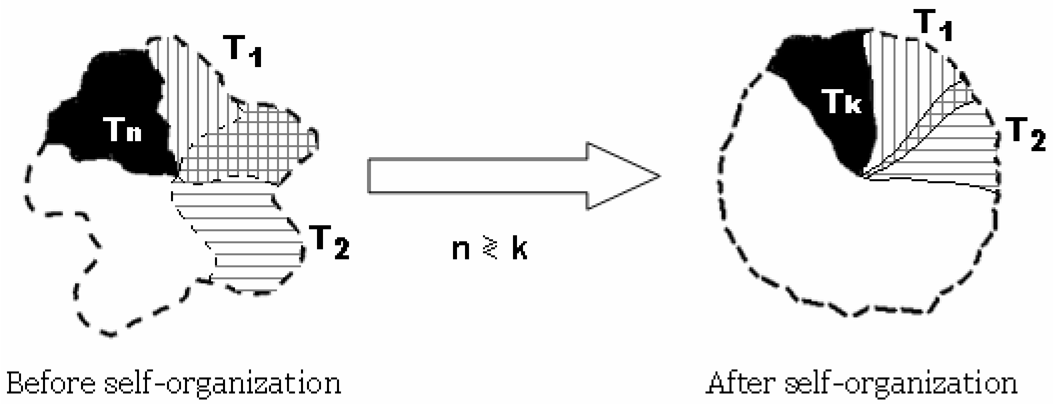

Fig. 8 VPL as a flexible division of labour and self-organization

In Fig. 8 we see that at the beginning of the creative process, the problem in hand is not well defined, which we denoted by dotted line along the perimeter. Tasks often overlap and their limits are not well delineated, which is symbolised by waved lines. After the self-organization stage, the problem is much better defined (it is almost a circle), the overlapping of tasks are substantially smaller and their limits are almost straight lines. If at the beginning the problem is divided into *n* tasks $T_1, T_2, \ldots, T_n$, then after self-organization it is divided into *k* tasks, $T_1, T_2, \ldots, T_k$ where *k* can be equal, bigger or smaller then *n*. We conclude that VPL allows of a **flexible division of labour**, while CPL is based on a **rigid (stiff) partition of labour** (see Fig. 9), where production/service process is well defined - it is a circle - the jobs $J_1, J_2, \ldots, J_n$ do not overlap, the limits between them are straight lines.

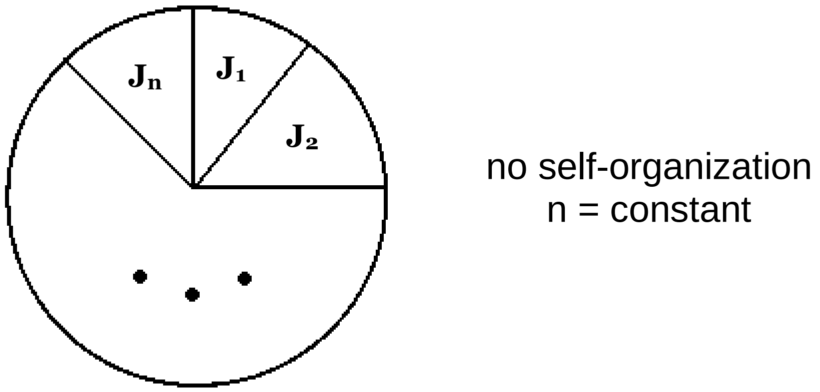

Fig. 9 CPL as a rigid partition of labour

Definition 2 Virtual Production Line (VPL) is a **division**, in general not a partition, of a complex creative process into more or less precisely described tasks (jobs), combined with **modern ICT**. The division of the creative process into tasks as well as the number of tasks may be changed throughout the process by actions of experts involved in it. Such a modification is called **self-organization of virtual production line**. Self-organization may recur over the creative process.

We note that unlike CPL, VPL is not a division of labour alone but combination of labour division and self-organization with modern ICT. Therefore, we can make two conclusions:

Conclusion 1 (The Past) Modern ICT increases substantially the efficiency and the value of social capital.

This is true insofar as we realize that social capital became a subject of serious studies only in 90's when we began to be able to send information electronically to virtually every corner of the world at almost zero cost. By comparison of Case 6A below with the process of designing a new car in the pre-Internet era, say some 25-30 years ego, one can see how important role modern ICT plays in construction of VPL.

John Chambers, chairman and chief executive of Cisco, world's biggest maker of data networking equipment, gives one more example of the importance of ICT in solving business problems (by our standards, running VPL). Cisco's acquisition in 2005 of Scientific Atlanta, a maker of set-top cable boxes for US $ 6.9 billions took 45 days. The popular feeling was that the contract was signed, or VPL run, at a break-neck speed. 18 months later, in 2007, Cisco bought for US $ 3.2 billions Webex, a web conferencing and on line collaboration company. Using a new high-end videoconferencing system, the entire process, including the signing of the final contact, took only 8 days. "There was no data room, it was virtual" – says Mr. Chambers (for details see FT of July16, 2007). The problem was solved, or the VPL run, in only 8 days.

Conclusion 2 (The Future) The history of improvement/development of CPL delineates directions for research on VPL. In fact, VPL is a natural development (phase) of CPL.

We may say that VPL is an instrument (a virtual transition belt) that experts use to combine codified knowledge with their tacit knowledge, competence, experience etc., to produce improvements in products, services, technology and management, and contribute to the world's stock of knowledge, both codified and tacit (see Fig 7). Otherwise stated, it is a device on which social capital of the firm is making money (financial capital) for firm *F*, using human capital of its experts and its physical capital (computers with software, data bases, communication networks, patents, licenses, books, buildings, furniture, etc.), acquired with a view to creative process. VPL is a heart of the **managerial model** for social capital analysis.

We conclude this Section with two examples:

<u>Example 4A</u> Let us consider the creative process of designing a new car using the latest achievements of material science, electronics, satellite communication, engine construction, etc. Experts assemble on VPL parts of knowledge representing those respective sciences, using their tacit knowledge and expertise to produce a project of a new car - documented in databases and in its hard copy, with computer codes for robots, strategy for marketing of the car, etc. So we see that VPL sometimes is very similar to the classical assembly line.

<u>Example 4B</u> We can consider a TV News Room as VPL which starts every morning with the analysis of ongoing and coming political/social events and closes at the main evening news issue. Using VPL we can study how new knowledge (news) is created and how codified knowledge (historical material, reportages, etc.) is combined with tacit knowledge (journalistic skills, personality, etc) to produce new codified and tacit knowledge. It will be interesting to do a comparative analysis of a few selected TV broadcasting stations and to study for them the relations between tacit and codified knowledge in the past and present.

4.3 Four forms of proximity

For obvious reasons workers (blue collars) are located and work on CPL in geographical sense as close as possible to each other. Experts (white collars, actors, etc.) may be located apart from each other, but they collaborate (work) on VPL because their competences, knowledge (both tacit and codified), experiences, etc. are close or complementary, they work in the same or similar organization, within the same or closed organizational culture, etc. In short, actors cooperate on VPL if they are close to each other in many senses, but not necessarily if they are geographically close. To analyze cooperation on VPL, we will use the concept of proximity introduced and developed by the French proximity school (Torre and Gilly [6], Torre and Rallet [7], Rallet and Torre [9] and Torre [8]), and recently studied by Menzel [10].

Proximity literally means nearness, closeness, contiguity and propinquity. We will use this proposition to describe relations between different actors working on VPL or as a central concept in our analysis of social capital. Like capital, proximity is complex and multidimensional and depends on time as capital does. Menzel [10] demonstrated in a deductive way that there are four forms or dimensions of proximity:

1. **Technological proximity (TP)** or **cognitive proximity** describes the so-called cognitive distance between actors, differences and similarities in the shared knowledge (both codified and tacit) that are relevant to problem solved on VPL, technological distance between them, etc. Technological proximity between actors exists, that is they are technologically close, if technology-related collaboration between them is possible for a given moment/period of time *t* in the past, present or future on a given VPL, or in solving a given problem.

2. **Emotive proximity (EP)** is related to personal relations, emotions, common experiences, trust, etc. between two particular actors. Emotive proximity forms a social environment which always surrounds any such cooperation. Emotive proximity between two actors exists if such cooperation between them is possible for a period of time *t* in the past, present or future on a given VPL.
3. **Spatial proximity (SP)** describes the geographical (spatial) context of cooperation, the ability and possibility of actors to engage in face-to-face contacts. We note that in the Internet era spatial proximity is not a permanent thing, but generated temporarily, whenever necessary (Torre [8]). Scientific conferences, kick-off meetings, industrial fairs, working lunches/dinners, etc. are examples of spatial proximity. Spatial proximity exists between two actors when it is possible for them to engage in face-to-face contacts, whenever it is necessary, for a period of time *t* in the past, present or future on a given VPL.
4. **Organizational proximity (OP)** describes the organizational context of a relationship, a structure or framework (like firm, network, cluster, etc.) that defines contacts between actors. Menzel [10] calls it structural proximity. Organizational proximity between two actors exists if it is possible for them to cooperate within a given organizational structure at any time *t* in the past, present or future on a given VPL.

The first two proximities describe direct interactions (relations) between actors, teams, etc. therefore we call them **direct proximities (DP).** We hardly imagine robots working on a given VPL, i.e. solving a given problem, although the work of experts on VPL will be changing alongside the improvement of ICT – see the Cisco case in Section 4.2. The last two proximities describe indirect factors that influence contacts between them, so we call them **indirect proximities (IDP).**

Proximity is a subjective description of a given relation done by an actor or actors involved. We have defined the above four forms of proximity in a very specific way to facilitate introduction of **the utility measure *u* of a given proximity** , called in short **proximity *u*,** as a binary function defined in the following way:

Definition 3 Technological proximity between actor *X* and *Y* equals

$$u\,(TP,X,Y,t) = \begin{cases} 1 \text{ if } X \text{ has a technology-related collaboration with } Y \\ 0 \text{ otherwise} \end{cases}$$

for any time *t* of their mutual relation in the past, present or future on a given VPL. More advanced measure of this particular proximity will be discussed in Section 5.

In similar way, we can define **emotive proximity *u(EP,X,Y,t),*** **spatial proximity *u(SP,X,Y,t)*** and **organizational proximity *u(OP,X,Y,t).*** We observe that - in general - emotive proximity is **asymmetric,** as the fact that actor *X* trusts actor *Y* at a given moment *t* on a given VPL, does not imply that *Y* trusts *X* at the same moment *t* on the same VPL. So, in general,

$$u(EP,X,Y,t) \neq u(EP,Y,X,t).$$

The same reasoning shows that technological proximity is asymmetric too. It follows directly from the above definition that both spatial proximity and organizational proximity are **symmetric**. Thus we formulate

Lemma 4 Both technological proximity and emotive proximity are asymmetric, therefore direct proximities are asymmetric. Both spatial proximity and organizational proximity are symmetric, therefore indirect proximities are symmetric.

Evaluating or assessing indirect proximity we can choose to ask only one actor, *X* or *Y*, while evaluating direct or asymmetric proximity we have to ask both actors X and Y at a time. One may easily observe a striking likeness between the four forms of capital and the four forms of proximity (see Fig. 10 and compare it with Fig. 4).

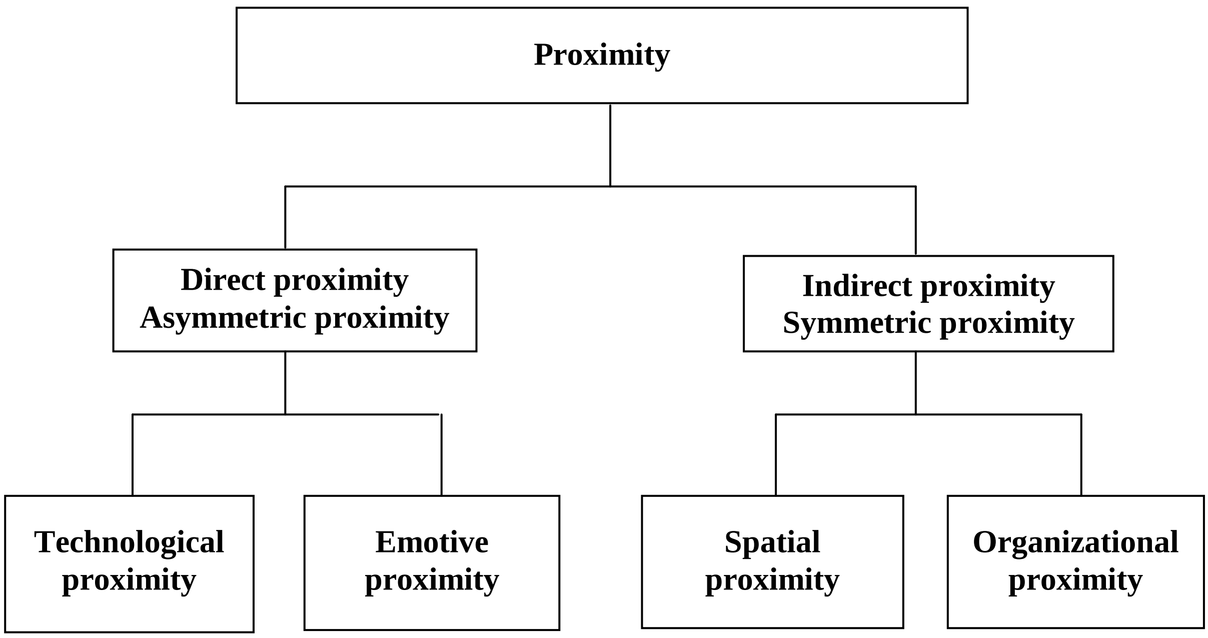

Fig.10 Four forms of proximity

Clearly, direct or asymmetric proximities are disjoint with or orthogonal to indirect or symmetric proximities. Consider an instance of technological cooperation (technological proximity) between two experts X and Y on a given VPL looking for a solution to a given problem. Since such cooperation may or may not be going on another VPL and emotive proximity is always surrounding contacts between X and Y, then technological proximity is disjoint or orthogonal to emotive proximity. Since spatial proximity is defined by face-to face contacts (geography) and organizational proximity concerns organizational structures, then they are disjoint or orthogonal to each other. That way we prove

Lemma 5 Technological proximity, emotive proximity, spatial proximity and organizational proximity are mutually disjoint and form a partition of proximity as entirety.

5 Generalizations and conclusions

We finish this paper with four concluding remarks containing short descriptions of subjects for further studies.

5.1 The system and its two subsystems

In Section 3, we have partitioned all assets (entire capital) of firm *F* into the following four forms: **financial capital (FC)**, which is, generally speaking, all that the firm's banking accounts and accounting records show, **physical capital (PC)** – anything else of material existence, **human capital (HC)** - anything in the heads, hands and legs of workers regarded as individuals, and finally, **social capital (SC)** – all the rest of the intangible assets of the firm. All these four forms interact to produce the **value of firm *V(F).*** In Walukiewicz [12], we extrapolate this reasoning to the national/regional level and describe how **new GDP** is produced by these four forms of national wealth.

Consider again Fig. 1 and Example 2A, but now with four inputs: **labour *(L),*** which is equivalent to our concept of human capital, **capital *(C),*** equivalent to the combination of financial capital and physical capital, **technology *(T),*** viewed as a measure of (technological) development of physical capital and, finally, the new input – **networking *(N),*** which describes how people (workers) cooperate or trust each other, or how easy it is to build a network in a given group, society, etc. The new input *N* is shown in Fig. 11 in a dotted arrow. An output of the system is a ***new GDP*** or ***V(F),*** depending on whether national/regional economy or firm *F* is modelled. So we consider national/regional economy as a **megafirm** (closed system) which transforms its inputs (labour, capital, technology and networking) into its output *new GDP*.

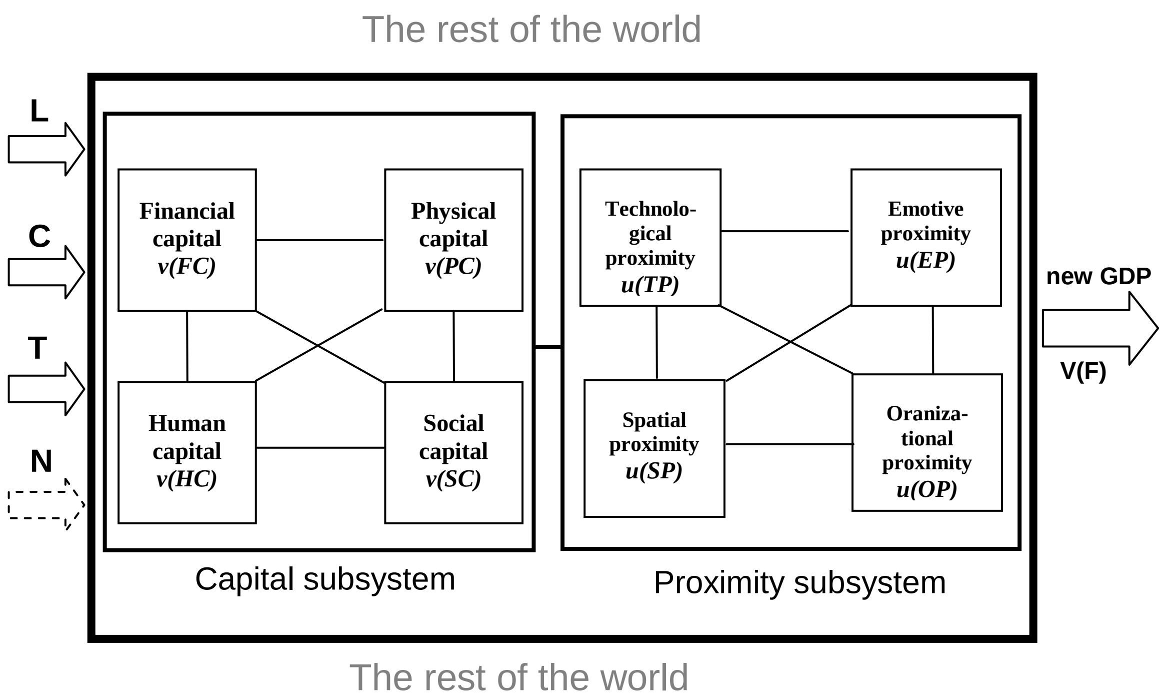

Fig. 11 The system and its two subsystems

Instead of studying relations between inputs and the output of the system, as we did in Section 2, we would ask: what is hidden inside this system? What mechanism transfers inputs into *new GDP* or *V(F)?* Based on the foregoing enquiries and analyses, we postulate that there are two subsystems in the system in Fig. 11: capital subsystem and proximity subsystem. Under graph theory, they are identical - they are full graphs with four vertices. We have demonstrated in Section 3 and 4 that **the elements of financial and proximity subsystems are mutually disjoint or orthogonal to each other and they cover the entire capital (wealth) and entire proximity**.

5.2 Orthogonality of inputs and questionnaires in social sciences

The last sentence tells us that there exist only four forms of capital and four forms of proximity. So, further studies in this domain should not go wider by adding new forms of capital or proximity, but should go deeper into a more advanced level of analysis. For instance, let us assume that our research study on social capital is done on level zero. Then at level one we may study internal and external relations of firm *F* (see our definition of social capital in Section 3). At level two we may study market-related external relations, production-related external relations and, finally, environmental-related external relations and so on (Westlund and Nilsson [19]). We believe that if there was a questionnaire following this concept, it will be easier to elaborate results and obtain stronger conclusions, as all chapters, subchapters and questions would be orthogonal to each other. This should be regarded as an outline of the first approach to further efforts in this field. In the second approach, more advanced methods should be explored for assessing and even measuring capital/proximity forms in terms of volume and value.

5.3 More advanced measures of proximity

We outline the second approach to the issue of **technological or cognitive proximity (TP)**. Let *c(X,Y)* be the **cognitive distance** between actor *X* and *Y* working on a given VPL, i.e. solving a given problem. So, *c(X,Y)* is the difference in knowledge - relevant to the VPL - between *X* and *Y*. If the knowledge of *X* is identical with that of *Y*, that is when *c(X,Y) = 0,* then **technological cognitive collaboration** between them is not possible and there is zero utility of their proximity - *u(X,Y) = 0.* The same thing happens in another extreme case, when e.g. *X* knows all about the problem on VPL and *Y* knows nothing. We denote this case by *c(X,Y) = 1* and observe that then *u(X,Y) = 0* again. We conclude that as *c(X,Y*) changes gradually from *0* to *1*, the utility of cognitive proximity in this relation changes accordingly, from *0* to $u_{max}(X,Y)$, but then goes back to *0* as is shown in Fig.17.

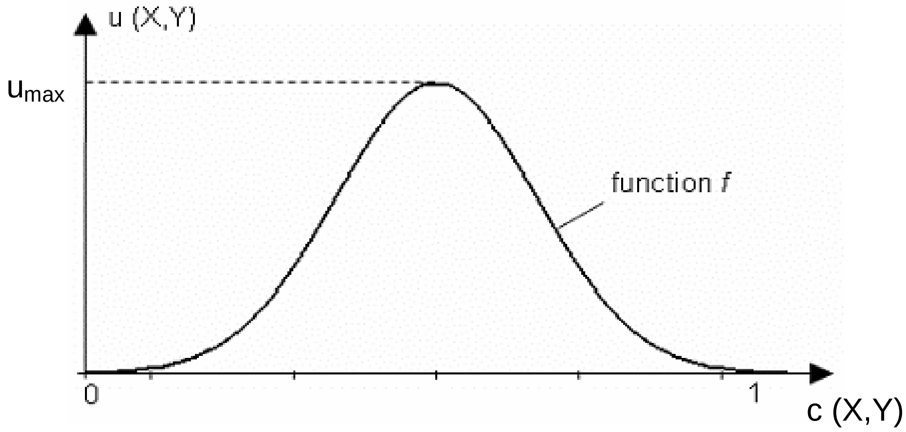

Fig. 12 The utility of cognitive proximity

If we knew the function *f*, such that

$$u(X,Y) = f(c(X,Y))$$

for at least some, say, “typical” relationships on a given VPL (e.g. relations between experts with analytic mind and open-minded specialists etc.), then we would do better in creating a team for a given VPL and assigning tasks to experts. So, in reality, the function *f* is not a binary, contrary to what we assumed at stage zero of our analysis (see Section 4 and Nooteboom [18]). We claim that **assignment problem**, i.e. the problem of assigning experts to tasks in an optimal way will be one of the most interesting questions in further research on VPL, as it is in the case of CPL. Problem which we will consider in the last remark below may be viewed as complementary to the assignment problem.

5.4 Evaluation of the FP's proposals

We can consider the evaluation of proposals submitted to a given call for proposals as VPL. It seams interesting to include our research findings on social capital and proximity in the ex post and ex ante analyses of such proposals and projects (analysis of evaluation methods, proximities and cognitive distances between partners in a given consortium, role of a coordinator, etc.). We hope to work out useful suggestions and recommendations for such evaluation procedures.

Finally, we argue that in new economy big organisations combine CPL with VPL. In fact, generally speaking, they run a number of classical production/service lines turning out goods and/or services, and a number of virtual production lines for solving different problems throughout physical production. A virtual production line makes innovations and improvements in a very broad sense viewed as a change for the better on a 'here and now' basis for the market to accept them. Since for a vast majority of SME`s creating VPL is practically impossible, this economy segment turns attention to clusters, where along with research institutions, universities, etc., they build a virtual production line to solve problems they face. This is the essence of the innovative industry in new economy.

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