Economic productivity and value creation under various organizational configurations of business processes

- A toolkit for phase transitions -

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Abstract

In this article we connect the economic concept of productivity and the business concept of value creation with different “ideal type” organizational configurations of business processes. We argue that these different configurations can be regarded as phases in a transitional process. We argue and demonstrate that the different configurations show radically different levels of productivity and value creation, depending on the complexity of their environment.

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1. Introduction

Various organizational configurations have been described in literature to shape business processes to the needs of markets and the nature of organizational resources. Apart from differences in these conditions in the eco-system, the archetypes of organizational configurations also represent aspects of evolution as has been outlined by Van Asseldonk (1998). In last years contribution to ECCON Van Asseldonk & Vos (2007) described the concept of process hierarchies as a method for configuring business processes to overcome the limitations of Taylorist principles (Taylor, 1911) for modern organizations working under conditions of unpredictability and heterogeneity.

One of the problems in applying such principles is the inadequacy of the definitions of economic productivity in economic science. Historically economists express the productivity of an economic entity as the relation between inputs en outputs measured in units. While this might work well in a rather homogeneous world, this concept becomes unusable in a world that is both heterogeneous in terms of inputs, as well as in terms of outputs. As a result, even at macro level, about 80% of the value generated cannot be attributed to this expression of productivity and is consequently called “residual” (Solow, 1957; Zegveld, 2000).

At the micro-level, the individual company or small clusters/networks of companies, it is equally impossible to measure productivity in the terms of classical economics. Yet, in order to understand the effect of organizational configurations, a uniformly applicable expression is required to understand the relation between various configurations and the business eco-system, and to gain insight into aspects of the phase transition between such “organizational states”.

This article addresses the problem described in 3 steps:

- It firstly develops a new definition of productivity. This definition is consistent with the classical definition of economic productivity in (semi-) homogeneous worlds, but is also applicable under conditions of heterogeneity and at any level/configuration of economic actors.
- Secondly it defines a set of economic actors that can be organized in alternative, archetypical, organizational configurations following Van Asseldonk’s (1998) evolutionary grid: capacity, industrial (Taylorist) and networked.

- Thirdly it demonstrates the behavior of these configurations and characterizes it in terms of economic productivity under various conditions of heterogeneity and predictability in the relevant markets.

Especially of interest is the behavior of respective configurations when the market environments are becoming less favorable for the configuration concerned. In these cases, a phase transition to another archetype is required in order to survive.

2. Productivity and value creation in heterogeneous environments

A definition of productivity

“Productivity” is in economic theory the word that expresses the relation between the inputs and outputs of an economic system. This economic system can in principle be defined as any collection of economic actors (country, region, sector, company, etc.) although in classical economics countries are largely the object of interest. Purist economists calculate productivity preferably in units to exclude price effects.

This purist principle has been compromised in neo-classical economics, because often the output (of a country) is measured in monetary units, be it corrected for inflation. The need to express the nominator in monetary value results form the heterogeneous nature of the outputs measured at country level, hence the inability to sum units of output at that level of aggregation.

However, when measuring labor productivity, the denominator is still being expressed in units of labor (“hours”). This means that labor is still conceived to be homogeneous as it can be counted in “hours”. In modern economies this is highly disputable as the nature of these labor hours can be highly different in the range from unskilled labor to highly skilled knowledge workers. This issue is recognized and resolved in economics by distinguishing sub segments of the system, like the distinction between a “production sector” and an “R&D sector”, or between “physical labor” and “knowledge labor”. However, as the number of sub segments increases with heterogeneity of labor, and many actors (e.g., companies) within themselves have a highly heterogeneous composition, the problem that has been recognized for the output measurement, is now also hampering the input side of the equation. Hence, in today’s economic systems it becomes inescapable to find solutions for measuring the denominator (outputs) that are similar to the solutions for measuring the nominator (inputs).

Example

Let us consider a company that creates output V as with H labor hours from its unskilled workforce. The labor productivity would then be V/H. If we then replace the unskilled workforce with highly skilled workforce, also working H hours to achieve output V (all under conditions for constant prices), it would mean that in the definition of economists the productivity has remained the same. Giving the waste of talent in this example, this definition does not seem to express the intended meaning: how many resources are needed to create a specific economic output.

The logical way forward is to measure the denominator also in monetary units and, similar as is done for the nominator correct for monetary value changes to exclude external effects (this is where the conventional preference for calculating in units comes from). A normal way of correcting inflation is through the consumer price index (CPI). This has disadvantages for correcting in the case of multinational companies: which CPI do we use? Do we use the CPI of the country where the company headquarters are? Do we try to decompose the company's outputs and inputs to the different countries in which the company is active and use the respective country CPI's? Obviously, for large multinationals, this is undoable. Sometimes inflation is corrected on a sector-basis; this runs into the same kinds of problems: many companies are active in many different sectors; decomposing company-level inputs and outputs into different sectors is obviously undoable. We therefore need a generic correction factor, like a worldwide consumer price index. A practical way to calculate such a correction factor might be to use the so-called "Hamburger-index".

The next issue is how to calculate this, using published data of an economic entity. Let us take the accounting scheme of a company as example:

Normalized accounting scheme:

Turnover (TO)
-/- VAT
-/- Purchased goods and services (B)
-/- Employment costs (EC)
-/- Interest on loans (I)
-/- Profit Tax (T)
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= Shareholder income

In the above scheme, asset depreciation is a way of accounting for purchased (capital) goods by spreading the cost consequences over a number of accounting periods and/or dividing these costs according to the speed with which the assets are used up. They are therefore are part of B.

An interesting issue arises with respect to how to define "output". Looking just at a single company, output is based on the number of units that leaves the company, or to units*prices = turnover (corrected for inflation or not). At a higher level of analysis, e.g., supply chain, sector, or country, we cannot just add the turnover of all companies, but we have to account for internal deliveries. Applying this logic to other entities like companies, sectors, chains, regions, the question arises what we consider to be "within the system" and what as a consequence is not part of the system. In economics this problem is "solved", by defining output not as turnover, but as added value. Added value is defined as "turnover minus purchases". Summing the added values then supposedly makes it possible to calculate system output. This is of course convenient, but does not solve the philosophical issue. Calculating added value we also have to make a choice of which actors to include in the system (their contributions are part of the added value) and which to exclude (part of purchases).

For companies, we for the moment adhere to the (stakeholder) view that:

- Governments are to be considered as suppliers of infrastructure and services (in exchange for which the company pays them VAT and profit taxes), and hence are outside the system.
- Interest is the price of money supplied by external money suppliers and hence is equivalent to suppliers of other goods and services
- Employees and shareholders are considered part of the system. Note that in an Anglo-Saxon shareholder view employees would be considered as "outside the system".

Depending on one's stakeholder definition chosen, the productivity measure might differ. When shareholders are seen as the only stakeholder, the productivity measure would be: Output / Nominal capital invested. When we include employees, the productivity measure is Output / *f*(nominal capital invested; hours worked).

On other levels of analysis, a considerate choice has to be made which stakeholders to include and which to exclude. On the level of a supply chain, supply partners would be part of the system. On the level of a business ecosystem, supply partners and capital providers would likely be counted in. On the country level, also the government would be counted in.

Mathematical representation

In the drawing below a general representation of an economic entity is drawn.

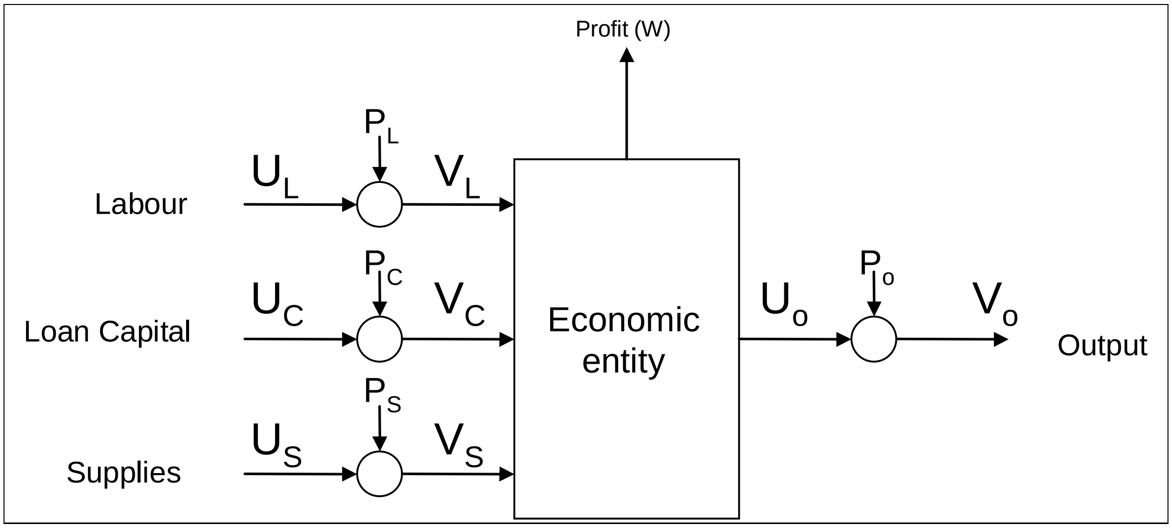


Figure 1: Representation of inputs and outputs of an economic entity

This entity receives inputs from surrounding actors (labor, [loan] capital, supplies) in units (U) that represent a money value (V) by multiplying these units with the prices of these units. It similarly generates output units (U_o) that represent a turnover (V_o) by multiplying the units with the market price P_o. The actual prices P can be split in a reference price P(0) and a price index Pi at t = T:

$$P = P(0) * Pi(T), \text{ where } \qquad Pi(T) = P(T) / P(0).$$

The economic expression for labor productivity (LP) of this entity is:

$$LP(T) = U_o(T) / U_L(T)$$

If we substitute the U's in LP with V / (P(0)*Pi) then we can write:

$$LP(T) = V_o(T) / V_L(T) * (P_L(0)*P_Li(T)) / (P_o(0)*P_oi(T))$$

Having expressed labor productivity both in real and monetary terms, we can relate it to measures of company strategy as measured in monetary terms.

Three strategic value drivers

Based on Porter's (1980) theory of competitive strategy, Van Asseldonk (1998) derived three strategic value drivers with which the strategic direction followed by a company over time can be measured and characterized.

Volume

Some firms choose volume as the dominant driver for value creation. Such firms often focus on strong autonomous growth, often operate in growing markets and strive to grow faster than the market. This strategy is reflected in statements as: "Our strategy is to grow 25% per year." With volume as dominant driver firms manage operational efficiency and product differentiation within the context of their aspired volume growth. Volume is defined in monetary terms as $V_o(T)$.

Efficiency

Other firms select efficiency as their dominant driver of value creation. Their strategic objective is to improve productivity with certain percentages every year. Quite often these firms compete in stagnating markets and they compete with other firms on operational excellence by investing in automation and mechanization. These firms try to maintain or increase their market share by offering lower prices than competitors. These firms create their value for the larger part by improving their cost structure. The efficiency parameter E is defined as volume divided by employment costs, both in monetary terms. It is calculated as follows:

$$E(T) = V_o(T)/V_L(T).$$

Relating efficiency to labor productivity gives:

$$E(T) = LP(T) * [(P_O(0)*P_Oi(T)) / (P_L(0)*P_Li(T))]$$

Differentiation

Lastly there are firms that select differentiation as their dominant driver of value creation. These firms emphasize product development and branding. They introduce new products with a higher added value either by improving the quality of the product itself or by investing in brand image and brand leadership. Such firms build a broad assortment of products to serve various segments in the markets in which they operate. The differentiation parameter D is defined as added value divided by volume, both in monetary terms. Added value = $V_L(T)+w(T)$, so that differentiation can be calculated as follows:

$$D(T) = (V_L(T)+w(T)) / V_O(T) \text{ or } (V_L(T) / V_O(T)) + (w(T) / V_O(T))$$

Relating differentiation to labor productivity gives:

$$D(T) = (P_L(0)*P_Li(T)) / [LP(T) * (P_O(0)*P_Oi(T))] + (w(T) / V_O(T))$$

In this way we have linked the economic definition of labor productivity to the monetary strategy measures. Hence there is no theoretical obstacle to calculate in money terms, provided adequate correction is made for the price indexes over the observed periods. This however is not a principle, but a practical problem that might be overcome by using the suitable references.

3. Productivity and business process configurations

Economic productivity is related to the configuration of stakeholders. As described above, the productivity definition (and hence the productivity) differs according to which stakeholders we include in and which stakeholders we exclude from our system definition. But more important, the productivity differs across configurations of stakeholders included in our system.

A very famous and simple illustration of this principle is the example of the pin factory by Adam Smith (1776). In Smith’s time, an experienced craftsman could, with help of the appropriate capital goods, produce about ten pins a day, or, when he did his utmost, certainly not more than twenty. After all, he would have to perform all the production steps himself and it is impossible for him to do more than one thing at a time. During a visit to a pin factory, Smith observed that the ten laborers that worked there could, with help of the same amount of capital goods, produce around 48.000 pins a day, or, that production increases disproportional with the amount of labor. The ten workers achieved this by dividing the tasks among themselves and specializing in performing one task each.

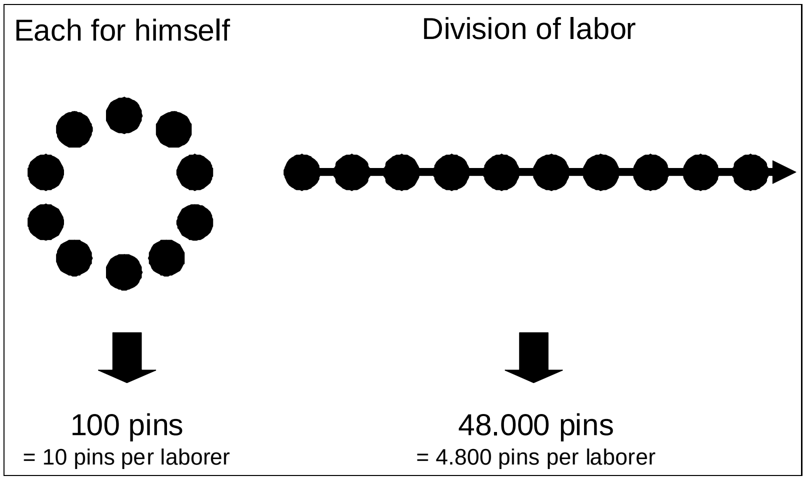


Figure 2: The productivity consequences of Adam Smith's example of a pin factory

If we look at the network configuration of the business process illustrated by Adam Smith, we see that the craftsmen all are working by themselves, i.e., in the production process they are not related to each other. This is a very specific network configuration, with only nodes and no relations. In contrast, the ten laborers who divide the labor among each other are related in a linear way, the output of the one being the input for the next one. This is also a very specific network configuration, with only one (directed) relation from each network node to the next node. The second business process configuration is spectacularly more productive than the first one, illustrating the point we make that the network configuration of a business process influences productivity. This is true, even if the nodes of this network (economically: the “inputs”) are all the same (homogenous).

The network configuration becomes even more important when the nodes are heterogeneous, e.g., when different laborers have different skills or capabilities. In such a case it makes sense to let every laborer specialize in the job that he is most skilled or capable for, thereby improving efficiency (E) and thus productivity. The key to improving productivity now becomes to find the best laborer for each job, or, in economic terms the best configuration of production factors. The larger the economic system (e.g., number of laborers), the larger the diversity of production factors (e.g., differences in types of capabilities between laborers) and the larger the number of possible relations between each of the production factors, the higher the chances become that an optimally efficient configuration of laborers will be found. This principle is not limited of course to laborers, but can be extended to the entire collection of production factors, i.e., different types of labor, capital, land and materials. In management terms this is referred to as the entire collection of different resources (tangible, intangible, financial) that can be accessed by a company.

Moreover, the abovementioned principle is not restricted to the “input” side of the productivity equation. A larger pool of different types of input factors makes it possible to configure an ever-larger number of different outputs. In management terms, the more different resources can be used, the more different products can be created by combining these resources in different ways. This principle is known from Schumpeter (1934), who described the entrepreneur as the one who makes a selection from the entire pool of different factors of production to come up with novel and unexpected combinations (“neue Kombinationen”). Through such novel and unexpected combinations, which we commonly refer to as innovations, companies can raise their sales and increase their prices, thereby positively influencing the output side of the productivity equation and increasing differentiation (D).

Of course, there is a cost attached to finding new, better, or optimal configurations of production factors. The higher the number of possible configurations, the higher the potential for optimally productive configurations (innovative outputs and efficient use of inputs), but the higher also the search cost to find such configurations. Therefore, when companies have found a certain configuration that works well, they tend to stick to it, and make only small incremental changes. For example, when a company has introduced a successful new product and can produce it in an efficient way, it will tend to reinforce this existing configuration and exploit it to the fullest. Only when the configuration becomes less successful and/or less efficient because of external pressures, the company will start exploring possibilities for new combinations (innovating). These principles are known as exploitation and exploration (March, 1991). It is known that in different environments, companies have to put different emphasis on exploitation versus exploration. In very certain and stable environments, companies can afford to focus on exploitation of existing configurations because these configurations may remain productive for prolonged times. In more uncertain and volatile environments, companies have to pay more attention to exploration of new configurations because the existing ones may grow obsolete very quickly.

4. Business phase transitions and business processes

From business experience, it was determined that different companies compete on different “ideal type” combinations between the strategic value drivers volume, efficiency and differentiation (Van Asseldonk, 1998). It is known that these ideal types correspond to different external environments, to different productivity developments, and to different configurations of business processes (Van Asseldonk, 1998; Zegveld, 2000; Zegveld & Den Hartigh, 2007).

Different relations between any two value drivers characterize different phases in the evolution of the business: capacity (craft-economy; volume-growth oriented), product/market (industrial economy; volume-efficiency and volume-differentiation axis) and mass-individualization (post-industrial; efficiency-differentiation axis). If the three drivers of value creation are combined with the three levels of business evolution, this creates a 3 x 3-grid which describes the evolution of value-creating structures over time.

Value creation has very distinct patterns. Some companies dominantly increase volume for long periods. Other companies predominantly steer on efficiency, and again others concentrate on shifting their differentiation level. Since the nature of these methods of value creation are rooted in the business processes, and are stable over prolonged periods of time, the characteristics of their business processes must differ as well.

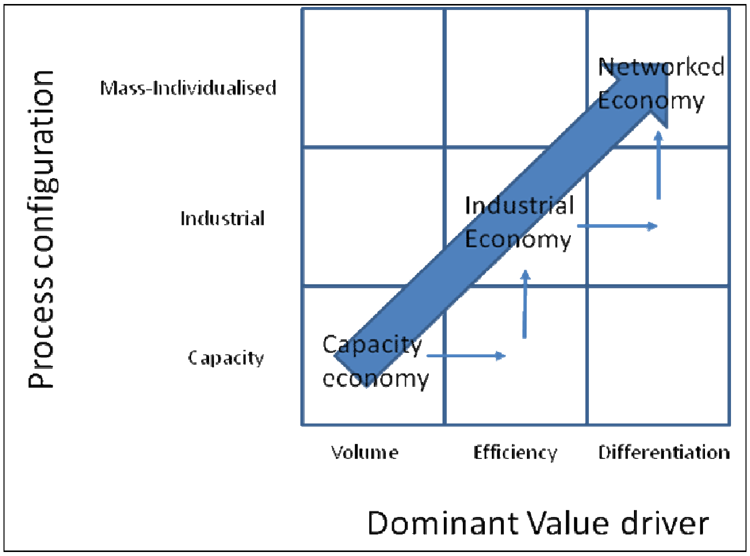


Figure 3: Business evolution grid

The only structural way to change the magnitude and orientation of the value creation is to change the underlying business processes: the marketing process, the manufacturing process, the information and know-how processes and/or the organization or behavior of the employees. In practice these changes develop in phases; in each phase the business processes have different characteristics.

The relation between the business processes and the dominant orientation of value creation is shown in figure 3. On the horizontal axis we see volume, efficiency, and differentiation as drivers of value creation. On the vertical axis, a distinction has been made between different kinds of companies with respect to the nature of their business processes: capacity-driven companies at the bottom, product-market-driven companies in the middle and mass-individualized companies at the top.

The simplest companies that we know are capacity companies. These are resource driven companies that merely sell raw materials, expertise or infrastructure capabilities, without adding much to these basic inputs. Examples of capacity companies include oil companies (exploration and trading), the traditional software companies or trucking companies that sell trucking per unit of capacity. Many consulting organizations also fit into this category, as they sell basic skills by the hour or any other unit of time.

Take for example a traditional software company that offers the services of programmers and system analysts to companies for which they develop proprietary software. In the sixties and seventies this was a booming business and some of these company owners became very wealthy: They created an enormous amount of value, as the salaries they paid their programmers differed greatly from the amounts they charged their clients for services rendered by these programmers. Inevitably, as the number of people with programming skills increased sharply, at some time demand and supply reached an equilibrium and the sellers' market became a buyers' market.

There may come a time when the software company suddenly faces a situation (when supply is larger than demand) in which its cost structure, developed in the good times, is no longer compatible with the world in which the company is active. And so the company is forced to cut costs. It might trade its expensive cars in for cheaper ones, reduce overhead and move to cheaper offices; in short, it does everything possible to regain profitability. The volume growth of the past, which in many cases surpassed 10-15% per year, has now dropped to a very low level, because each market player is fighting for a larger market share. In so doing, the software firm ceases to be an archetype capacity company. If we look at figure 3, we see that it shifts from the bottom left-hand corner position to the right and enters the capacity-efficiency mode.

In the process of cost reduction a cost minimum will be reached. In our software company, someone may remember the numerous financial programs that were developed for trading companies and come up with the idea of reselling this software, perhaps slightly modified, to all trading companies in the country, in Europe or indeed in the whole world. At that moment the software, which was originally proprietary-developed, more or less becomes a product. Its core is now re-used and supplied to similar clients in similar situations. So rather than selling its raw capacity (programmers' hours) the company now starts selling the product, which is the final result of that capacity. In communicating to the market it has to make clear and specify what product clients can buy.

This causes a revolution in productivity, because what was developed in the past at very high cost now becomes re-usable. This increases productivity enormously and the company, in terms of its processes, changes from a capacity company to a product-market company. Rather than being 'a jack of all trades' (within the qualitative limits of its resources), it now starts supplying a narrow spectrum of products to a few well-defined market segments. In the history of our industrial economy Ford's first production line for the Model T is one of the best and most clean-cut examples of a shift from the capacity phase to an industrial phase.

In this industrial phase companies will still grow, but in many cases growth is no longer organic, it is acquired growth, as similar companies in the same market are acquired in order to reach sufficient economy of scale. In this product/market business economies of scale mean that larger volumes (in terms of development cost of product, but also in manufacturing cost) will rapidly increase productivity. Therefore a company can gain hugely if it does not only rely on autonomous growth, but also takes over other companies. Since the market is no longer expanding sufficiently to sustain organic growth for all, a heavy shakeout takes place in which smaller players are taken over by the larger ones or simply fail. In the end a few large companies survive whose positions in the product/market segments in which they have chosen to compete, are very strong.

Inevitably, here too, a limit will be reached. Once the products have been fully engineered and optimized, product costs have neared those of its raw material. As all other development and manufacturing costs will now be amortized over a large number of products, their contribution to product cost has become fairly minimal.

In the meantime, already during the productivity improvement stage, most companies begin to realize that there is no single market for a single product. There are many product varieties for many market segments, so within one overall market segment there are different needs, which can be grouped in different ways. It has been Ansoff's (1965) contribution to strategic management that he recognized product/market segmentation as one of the basic possibilities for companies to manage their value creation. However, when a company starts making not just one but many versions of a product, inevitably the cost of the product will be higher than that product in its simplest, singular form. This is true at any level of technology.

Although the progress of technology enables a company to create product variations in an ever-cheaper way, it is still more expensive to make 60 versions of a car than just one single version in a single color. This was true in Henry Ford's time and it is still true nowadays in very sophisticated car manufacturing plants. What technology does enable is the reduction of the marginal costs below the marginal the value that is added to this product by differentiating it in the market place. Clients will pay more for something that fits their particular needs better than the extra cost incurred by the manufacturer. Therefore, differentiation by creating product heterogeneity is a very powerful method in creating value beyond the level of volume and efficiency. In many industries we still find the residuals of a move from capacity to product/market thinking, but in parallel we see almost immediately a shift towards more segmented product/market approaches.

Nowadays most advanced industrial companies manufacture and/or supply a wide range of product varieties for ever smaller market segments, because technology enables them to get closer and closer to the needs of their particular clients. However, in many industries this evolution is reaching its limits as well. Take for example the insurance business. Until quite recently, insurance companies were commodity-product businesses which all sold basically the same product to the same market. After a massive investment in streamlining and automating the supply chain (which reflects the efficiency move towards the product/market phase in that industry) insurance suppliers have recently started developing products that were almost tailored to an infinite variety of client needs. However, while investing in higher value-added products they threaten to loose gradually their relation with the market. Some of these products are now so complicated that clients can no longer find out what the various insurance policies offer for their particular situation. Consequently they lose interest. When it comes to insuring their car, their health or their life, insurance brochures may need about 15 pages to explain the difference of these various possibilities to clients.

The industry invests in better, more tailored products, but is meanwhile losing the connection with the market place. While it should obtain a higher price for a better product, the market can/will no longer understand the subtle differences between the various offerings and their implications. Therefore new intermediary companies act as a go-between and they take the added value by sorting out the problem for the client. The providers of the insurance policies are pushed back into cost cutting and price wars with these intermediaries who absorb the true added value for differentiation. This means that the insurance companies incur the cost of developing and supplying highly differentiated products, while they enjoy the income of a cost-driven business. Consequently most of these insurance companies, especially in damage insurances (as a result of the low switching costs) have a hard time finding a profitable way to the future. And this is true for many other industries as well.

Such a way of value creation has its consequences. The cost of adding features (even if they are fairly small per function) pushes manufacturing cost up. It requires development and manufacturing effort, making the cost higher than that of a standard product. But as customers no longer perceive the difference, they choose products on price. The end result here, too, is that the cost structure is typical of a differentiation industry, while the income structure typifies a cost-driven industry. This is because clients no longer recognize the attempts of the suppliers to create products that fit their particular purpose.

So there appears to be a growing problem with product/market based differentiation. The problem will increase if we extend this development in the direction of ever more fragmented markets. There is a natural limit to the ability of customers to recognize product differences and there is also a limit to their effort in understanding these differences. Therefore, we are reaching a situation in which adding features to products might become increasingly cheaper, but the ability to convert these product features into real added value in terms of price levels achieved in the market will be diminishing. The marginal returns of that evolution become negative. Many industries are currently facing this problem. They are stuck because the volume of the existing markets no longer grows enough. And the reason for that stagnation is not only that in their manufacturing processes they are approaching the minimum manufacturing cost of the product, but also that in the market place they have reached the limit of differentiation in the conventional sense.

The logic of reasoning the evolution through the 3x3-grid seems to exclude the extreme right-lower hand corner position (capacity/differentiation) as well as the three positions in the top left-hand corner (product-market/volume, mass-individualization/volume and mass-individualization/efficiency). In fact, these positions can be taken but they do not match the mainstream development. With respect to the lower-right-hand corner, companies find themselves in the position of capacity-differentiation are niche players and exploit a scarce craft.

In theory one could conceive situations where companies move from capacity to industrial stage, without having to go through the cost-cutting stage under pressure of stagnant market growth first. However, this would imply sufficient vision to change. It would mean starting transformation well before the external need is there, and we know of no company that has taken this course. Phase change seems to be forced upon companies, rather than being voluntarily sought. Companies do not evolve in a gradual way, but through phase transitions, where the change from one phase to the next profoundly changes the company's strategic orientation, the way value is created, the way productivity can be improved and the way the business processes are configured.

In other words, while companies go from phase to phase, all business processes change, not just in sophistication but also in their very nature. Whereas in the 3x3-grid a movement to the right merely indicates an improvement of the existing processes, a vertical shift means a completely new version of such processes. The process foundation themselves change. The diagonal positions in the matrix can be considered archetypes of economic organizations. The companies in the different "ideal type" positions vary greatly in the way they structure and organize processes. They seldom appear in their pure form, but their characteristics are easily recognizable as phases in an evolution chain.

5. Relation with complexity

Complex behavior emerges from interaction between actors in the system. Let us take a "simple" system of 11 actors, each actor with its own specific competencies, e.g., a football team.

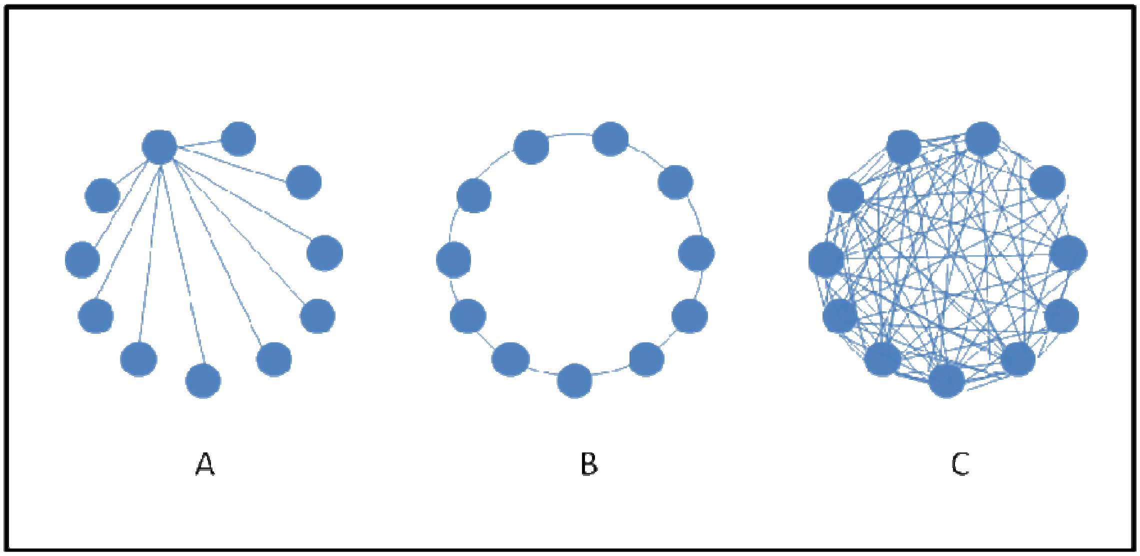


Figure 4: Archetypes of networks

In figure 4 the different network configurations of this system are shown through sketching the different types of connections that could exist, representing contacts or interactions between the actors (players). In configuration A all connections come together in one actor, in configuration B all actors are connected in a circle and in configuration C every actor is connected to every other one. If we take the example of the football team:

- In team A the players where all the connections come together is the central actor determining the entire game. All balls will be passed to and from him.
- In team B every player can only pass the ball to one of its neighbors.
- In team C balls can be passed on from every player to every other player.

In team A we recognize a strictly hierarchical system. The central player is the “boss”. In team C we recognize something chaotic. Team b is somewhere between those, but we cannot perhaps immediately imagine how this would work.

In the mathematical representation of these kinds of networks, three concepts are important:

- Connectivity: this is the relative number of connections present in the system (the existing number of connections divided by the total possible number of connections). In team A and B the number of connections is low (20 and 22, respectively, if we assume that every line represents two connections: one connection “coming in” and one connection “going out”) and so is the connectivity (respectively 20/100 and 22/110). In team C the number of connections is high (110) and the connectivity is maximal (110/110).
- Concentration: this is the extent to which connections are concentrated around single players. In team A the concentration is high (all concentrated around 1 player) and in team B and C the concentration is low (every player has an equal number of connections).
- The connectivity and the concentration together make up the third concept: entropy. The entropy concept comes from thermodynamics and information sciences and it indicated the extent to which a system is ordered or disordered. Low entropy indicates order, a high entropy indicates chaos. For the mathematical relations between connectivity, concentration and entropy we refer to an improved version of our article for the 2003 ECCON meeting (Van Asseldonk, Den Hartigh & Berger, 2008).

In figure 5 the morphology (configurations typology) of a real football team is indicated based on the ball passes in the game (in this case Feijenoord, from a game between Feijenoord and Roda JC). The thickness of the lines is a measure of the frequency of passes from one player to another.

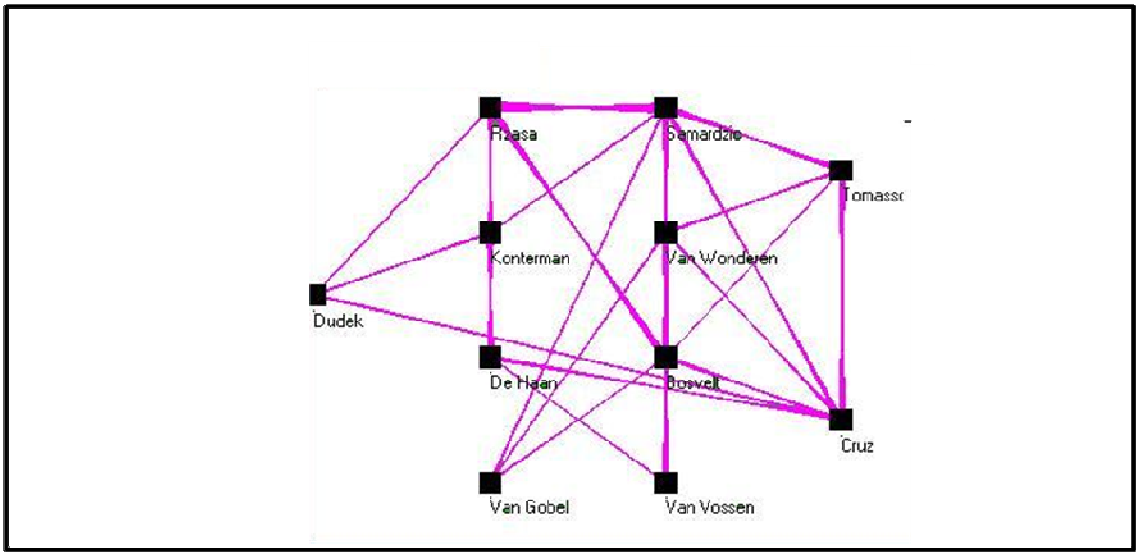


Figure 5: Morphology of Feijenoord from the match Feijenoord vs Roda JC

Notice that the morphology of the football team is more complicated than our models A and B, but substantially less complicated than model C. Apparently the morphology of a real football team is somewhere between the two extremes. That fits the general findings from our previous research, summarized:

- When the heterogeneity of the environment increases and the predictability decreases, teams using a hierarchical system like our model A are no longer able to create a large enough of solutions to be successful. The combinatory limitations are too strong and the demand is too unpredictable to work with strictly regulated schemes.
- In theory a team following model C is able to generate all possible solutions, i.e., within the limitation of the competencies of the 11 players or their combinations. However, within this total set of solutions there are so many non-productive and/or non-functional ones that the team cannot select the productive ones fast enough to gain an advantage. Much of the energy is wasted in chaotic attempts to find novel solutions.
- There seems to be a level of orderliness in the team that fits the level of heterogeneity and unpredictability of the environment (in the case of football teams, this reflects the playing qualities of the opposing team). In a simpler environment a relatively simple and/or network configuration can still be successful. In a more complex environment a more complex and adaptive network configuration is needed.

6. Morphology, productivity and value creation

However simple the above network morphology may seem, it is a powerful tool to illustrate the differences in economic performance of companies of different organizational archetypes in relation to the complexity of the markets they serve. The generic form of this relation seems to be first recognized by Ashby in his “Law of requisite variety” (Ashby, 1958). This Law states that there is an optimum of variety a system (in our interpretation, e.g., a company) should produce in its relation to the relevant environment (in our interpretation, e.g., a market). Too much variety is wasteful in resources, too little is wasteful in loss of opportunity value. Very much alike the football team example that was cited in the preceding section. However, this notion has largely been used in a qualitative descriptive way, and has not been linked numerically/mathematically to the value creation capabilities of a company with specific organizational morphologies and specific market characteristics.

In this article we aim to demonstrate these relations for the distinct archetypes that were shown in the evolution matrix (figure 3). We do this in a highly simplified way, using simple calculations. It is obviously possible to further develop these arguments into a comprehensive set of mathematical formulas. However this is outside the scope of this article. We merely aim to explain the principles and the primary findings. The computational model underlying the examples below enables to simulate a wide variety of internal and external conditions, and a selection has been made to illustrate the reasoning on phase transitions that was developed above.

In order to assess the impact of various morphologies on economic value creation we use the model for strategic value creation that was developed by Van Asseldonk (1998) which was explained in section 2 with the productivity definitions. We will start from the basic morphologies as displayed in figure 3: the capacity type, the industrial type and the networked type. In order to develop our argument, we first consider the capacity type. In principle, a company of this type can produce anything that can be made up from the collection of competences residing in the actors of the system. It does not matter whether these competences reside in a single individual or they are shared between a number of individuals. We consider such an individual or grouping as an actor, represented by a specific circle in the morphology diagram.

In this way our capacity company is represented as number of competence groups (see figure 6). All connections can be made and therefore this configuration is capable of producing anything that is within its scope of competences.

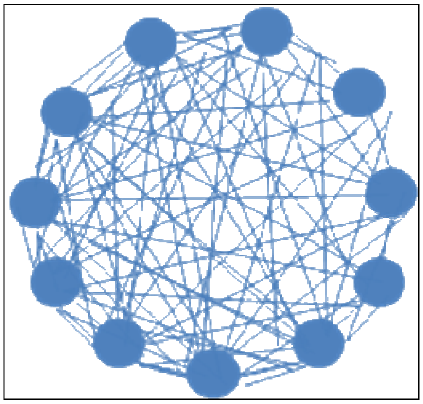
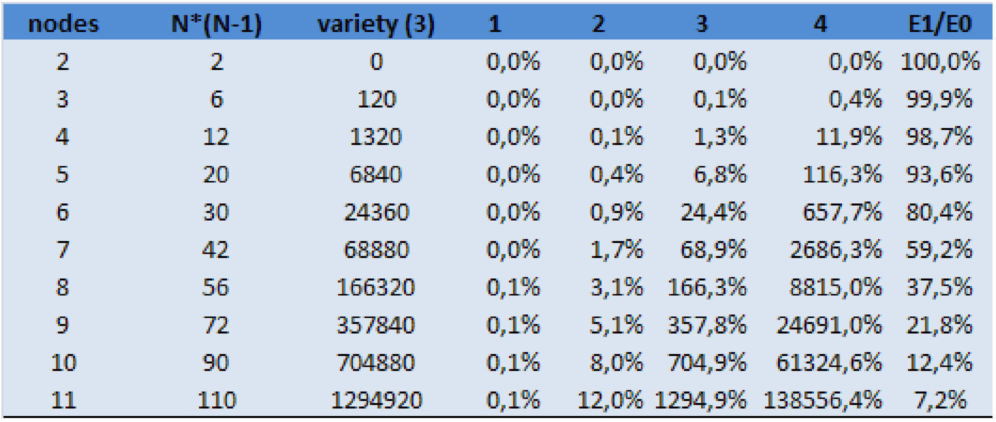


Figure 6: Capacity morphology

However, responding to a market request, the company has to find the right combination (and sequence) of competences to produce the aspired product or service. This search will require resources, the cost of which is added to the resources needed to produce the result once the adequate combination and sequence has been identified. Now assume the required response requires the combination of 3 competences. In an 11 point network there are 10 x11 = 110 links between the nodes. Numerically there are 110! = 110 x 109 x 108 x … x 1 = 1.294.920 different sequences of 3 competences possible, each producing a different solution to the clients problem, i.e., there is an immense variety of solutions.

The problem however is finding the right solution, and barring a pre-defined set of solutions, the network will have to find the right solution from its total set of solutions. If we assume that evaluating the alternative solutions until the organization finds the right solution on average will cost only 0,001% of the cost to produce the required solution, the following table demonstrates the enormous impact of the search energy on the efficiency (defined in term of human resource utilization) of such company.

For a number of competence nodes (ranging from 2 to 11) this table shows the amount of search energy required to find the adequate response to a market request for the number of competences required for this response (ranging from 1 to 4). The number of competences available in the system is in column 1, the number of available connections is in column 2, and the variety that can be produced with 3 competences is in column 3 (3 competences required is our reference case throughout these examples). Columns 4 through 7 display the amount of search energy required for sequences of 1, 2, 3 or 4 competences, respectively.



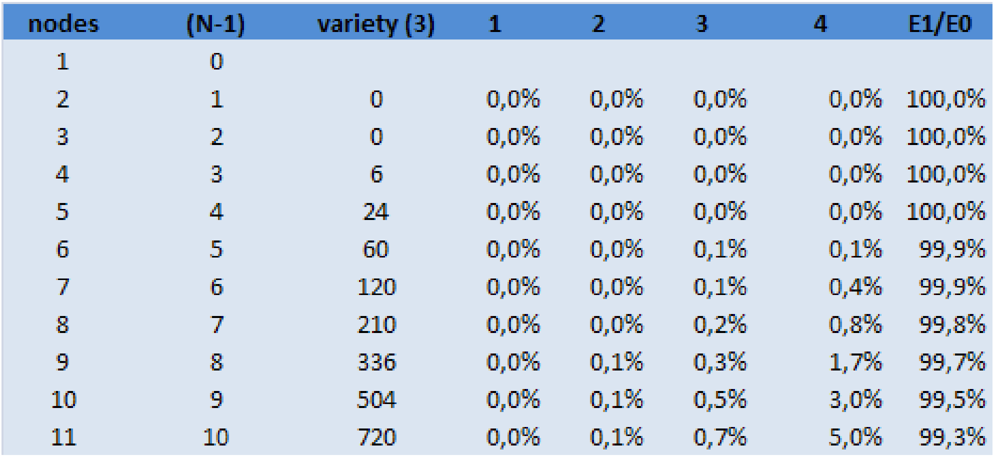
nodes	N*(N-1)	variety (3)	1	2	3	4	E1/E0
2	2	0	0,0%	0,0%	0,0%	0,0%	100,0%
3	6	120	0,0%	0,0%	0,1%	0,4%	99,9%
4	12	1320	0,0%	0,1%	1,3%	11,9%	98,7%
5	20	6840	0,0%	0,4%	6,8%	116,3%	93,6%
6	30	24360	0,0%	0,9%	24,4%	657,7%	80,4%
7	42	68880	0,0%	1,7%	68,9%	2686,3%	59,2%
8	56	166320	0,1%	3,1%	166,3%	8815,0%	37,5%
9	72	357840	0,1%	5,1%	357,8%	24691,0%	21,8%
10	90	704880	0,1%	8,0%	704,9%	61324,6%	12,4%
11	110	1294920	0,1%	12,0%	1294,9%	138556,4%	7,2%

Figure 7: Efficiency in a capacity configuration

This table clearly shows how with increasing numbers of available competences (vertical) and with increasing numbers of required competences, the amount of search energy as a percentage of the production energy increases rapidly from almost nothing to many times the multiple of the energy required to produce the solution. In the reference example of three required competences, it rises from virtually nothing with 3 competences in the system to a staggering 12-fold in a system with 11 competences. The impact on system efficiency for the 3-competence required reference case is displayed in the last column: the relative efficiency (compared with a system without search energy) drops from 100% to only 7,2 %.

In other words: in a system with an increasing set of competences performing more and more complex tasks the search energy becomes prohibitive for prosperous operation. We conclude that capacity systems are only suitable for simple tasks for which not too many competences are required and/or the pool of available competences is quite low.

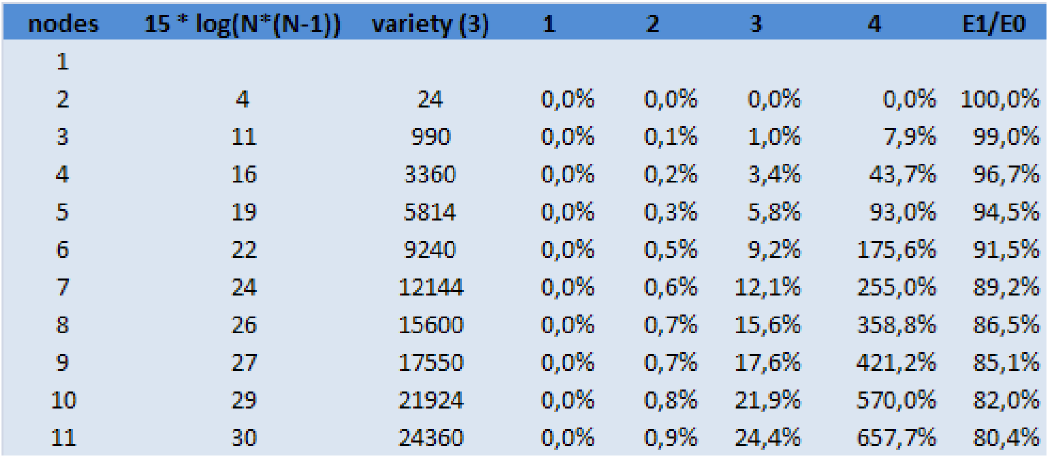
How different is this with the industrial version of our archetype 11-node system in the table below (for the network configuration of such a system, see configuration A in figure 4). Even in the most complex requirements, combining 4 competences from the available 11 competences the system requires only 5% search energy! However the price that is paid is a dramatic reduction in the variety of available solutions. Whereas the capacity configuration could offer over 1.2 million solutions, this archetype industrial morphology offers only 720 solutions from the combination of 3 competences. We conclude that it is highly efficient in complex tasks but offering a relatively small solution set. In the famous words of Henry Ford: “You can get it in any color as long as it is black”.



nodes	(N-1)	variety (3)	1	2	3	4	E1/E0
1	0						
2	1	0	0,0%	0,0%	0,0%	0,0%	100,0%
3	2	0	0,0%	0,0%	0,0%	0,0%	100,0%
4	3	6	0,0%	0,0%	0,0%	0,0%	100,0%
5	4	24	0,0%	0,0%	0,0%	0,0%	100,0%
6	5	60	0,0%	0,0%	0,1%	0,1%	99,9%
7	6	120	0,0%	0,0%	0,1%	0,4%	99,9%
8	7	210	0,0%	0,0%	0,2%	0,8%	99,8%
9	8	336	0,0%	0,1%	0,3%	1,7%	99,7%
10	9	504	0,0%	0,1%	0,5%	3,0%	99,5%
11	10	720	0,0%	0,1%	0,7%	5,0%	99,3%

Figure 8: Efficiency in an industrial configuration

Not surprisingly our networked morphology (something like the soccer team) offers a solution in between (see the table below).



nodes	15 * log(N*(N-1))	variety (3)	1	2	3	4	E1/E0
1							
2	4	24	0,0%	0,0%	0,0%	0,0%	100,0%
3	11	990	0,0%	0,1%	1,0%	7,9%	99,0%
4	16	3360	0,0%	0,2%	3,4%	43,7%	96,7%
5	19	5814	0,0%	0,3%	5,8%	93,0%	94,5%
6	22	9240	0,0%	0,5%	9,2%	175,6%	91,5%
7	24	12144	0,0%	0,6%	12,1%	255,0%	89,2%
8	26	15600	0,0%	0,7%	15,6%	358,8%	86,5%
9	27	17550	0,0%	0,7%	17,6%	421,2%	85,1%
10	29	21924	0,0%	0,8%	21,9%	570,0%	82,0%
11	30	24360	0,0%	0,9%	24,4%	657,7%	80,4%

Figure 9: Efficiency in a networked configuration

We have chosen to grow the number of available connections with a log function on the maximum possible connections multiplied by an arbitrary factor 15 (see column 2). We have chosen for a logarithmic relation because many natural systems display logarithmic relations, but in fact any mathematical expression growing the available number of connections slower than the possible number of connections will do.

A networked system with these parameters offers (again for solutions requiring 3 competences out of an available set of 11) 24.360 possible solutions requiring only 24,4% search energy. We conclude that it is better suited for a market that requires a large variety of solutions than an industrial configuration, and vastly more efficient than a capacity configuration for tasks of this complexity.

The picture becomes even more interesting if we look at the value creation performance of these systems under various conditions of market variety requirements. To demonstrate the impact of the different archetypes on value creation, we have assumed the following business characteristics:

Market size: 100.000 units
Market price: 100 €/unit
Materials cost: 60 €/unit
Labor cost: 30 €/unit
Price elasticity: 3

In order to calculate the value generated from the market we have used Van Asseldonk's (1998) value formula OCF = V*(D-1/E):

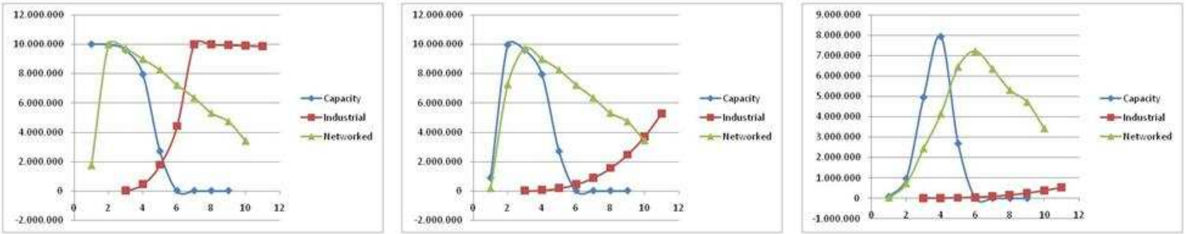
OCF = Operational Cash Flow, a measure of value created
V = Volume of Sales (units x prize)
E = Efficiency = Volume of Sales / Employment Costs
D = Differentiation= Added Value / Volume of Sales

As we showed in the section 2 of this paper, the value creation variables can be directly related to our definition of productivity. We further applied the following (stylized) assumptions:

- Market variety is evenly spread over the respective company varieties.
- The "natural market share" of the company is the ratio between offered variety (by the company) and required variety (by the market). It is assumed that competitors will satisfy the required variety not offered by the company.
- Making use of the price elasticity the company can influence its Volume of Sales in the market. By lowering prices it will attract business from nearby requirements, by increasing prices it will lose business to competitors. This mechanism is governed by price elasticity, which is assumed to be linear throughout the full price range. We have assumed companies to adjust prices and volumes to the point where it maximizes the value generated.

On this basis we calculated the value creation for the three archetypes under conditions of various levels of required (by the market) variety: 100, 1.000 and 10.000. Especially the higher end variety might raise questions. Hover, many of the products in modern markets do display this kind of variety. For example, Volvo only produced 2 completely identical cars on their 440 series, of which in total close to 600.000 were build. General Motors claimed to be capable to produce over 6 billion different versions of their Saturn model. How many different tea's and coffees are there on the market? And how many different kitchens, financial products and holiday packages can you choose from?

In the figure below the results are shown for these various variety requirements. The left graph shows the value creation performance of the respective archetypes under conditions of low required variety (100 varieties). On the horizontal axis the extent of the competence set of the company is shown, ranging from 1 to 11 distinct competences. It shows that capacity configurations (the blue curve) are superior in relative simple operations in terms of their set of available competences. Up till 4 or 5 competences the capacity (blue) and networked (green) configurations yield more value than the corresponding industrial (red) configuration. If however the required skill set grows beyond that point, the industrial configuration rapidly becomes dominant in its performance, especially compared with the capacity configuration. Networked configurations perform better in more complex tasks than do capacity configurations, but they too are beaten by industrial configurations.



Required Variety = 100 Required Variety = 1000 Required Variety = 10000

Figure 10: Value creation under various environmental requirements

A similar picture emerges at intermediate variety requirements (1000 varieties). Here, however, networked configurations are superior up to a higher level of required competences than in the first example. Only at the level of 10+ competences the industrial configuration becomes superior again.

At very high levels of required variety (10.000 varieties) the picture changes dramatically. Whereas the capacity configuration still only looks attractive at very low levels of required competence, the industrial configuration can only offer such limited variety compared to market requirements that it cannot compete anymore with the networked alternative. Throughout the whole range (except for the very limited competence mix) the networked configuration outperforms both other alternatives.

7. Conclusions

In this article we have reasoned that the classical economical definitions of productivity can be linked to Van Asseldonk's (1998) value creation model and its underlying parameters. This is of great importance because it enables us to apply productivity analysis to economic systems that are inherently heterogeneous both in terms of inputs as well as outputs. Next, we have reasoned that productivity is related to the network configurations of business processes. Then, we have explained how organizations evolve in business reality, responding to the pressures of their environments. To be able to formalize our analysis, we have argued based on the example of the football team, the relation between different network configurations and the complexity of the environment.

Based on this reasoning we have then applied the value model in calculating the differences in value creation form the various organizational archetypes that correspond with Van Asseldonk's (1998) phase transition model. It shows that:

- Increasing the required competence mix forces an organization to migrate from a capacity configuration to an industrial configuration.
- Increasing the variety requirements in the market forces a phase transition to a networked configuration.

Admittedly, the above reasoning has been based on highly stylized models of organization. However, in a "ceteris paribus" comparison the expected effects are clearly visible. Playing with the underlying model the effects appear to be robust and systematic. It is desirable, however, to develop the analysis into a fully developed set of mathematical equations to explore the general solutions rather than a set of specific solutions. Next to that, a simulation may help to understand more fully the extent of these behavioral differences and especially the boundaries within which they occur: what happens during a phase transition? Whereas the mathematics will restrict us to simplified examples, like the ones we used for this article, simulation might help us to understand the same phenomena in a richer configuration, more closely resembling the economic reality of today's dynamic and heterogeneous markets.

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