Report
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Network

The previous Report briefly described some of the physical achievements that form the basis of the digital revolution we experience every day. We highlighted the process of information digitization, giving digital technology its immateriality, the extraordinary progress of the microprocessor, providing unprecedented computational powers at the palm of our hands, and the vertiginous expansion of the connectivity infrastructure, mainly through the rollout of optical fibers. A fourth ingredient of a different nature is missing. It is the abstract structural component that aggregates, combines, synthesizes, and at the same time amplifies the effects of the previous ones. It is what we may call the network paradigm, which will be the subject of this Report.

An important feature of the digital technology world is that it is completely interconnected. Connections form networks. Contemporary relations and social arrangements, in particular economic ones, can only be understood within the logic of the structure, dynamics, and properties of networks.

The evolution of network theory is one of the most fascinating chapters in the history of modern science. In Dynamo Report 63, we had the opportunity to recall some episodes of this narrative. At the time, we sought to understand the nature of aggregate movements of financial markets, by seeing them as complex adaptive systems. A look at the topology of networks and some of their properties – *small world* behavior, high interdependence, extreme events, and presence of critical points – provided valuable insights for us. With the extraordinary increase in connectivity from the dissemination of digital technology, network theory has acquired an even higher prominence, becoming an indispensable tool to support the understanding of the contemporary world.

Let us quickly remember them. One result of the topology of highly connected networks is the property known as small world. The phrase emerged in 1967 from an experiment by Stanley Milgram, in which mail correspondences were distributed randomly and, surprisingly, results suggested that any two people on the planet are separated by a distance of at most six 'degrees' (six degrees of separation). Milgram's original insight was largely overlooked for thirty years, until in 1998, Duncan Watts and Steve Strogatz published a three-page article in *Nature* containing mathematical explanations and a graphic representation of the phenomenon. In the small world chart, some distant vertices have long-range connections, whereas adjacent vertices are more interconnected. Subsequently, it was found that this pattern of connections is present in several physical, social and biological phenomena, such as in the structure of our neurons. In this case, the adaptive motivation is clear: instead of travelling a long way between the various regions of the brain, synapses find shortcuts in transmission, producing quick answers, such as a reflex, "this is fire, get your hand off it". At the same time, if a part of the brain becomes damaged, this will not jeopardize the functionality of the entire system. In fact, studies show that patients suffering from localized brain injuries retain their abilities in other regions of the organ.

The architecture of neural networks in the brain illustrates two important virtues of small world structures: i) high capacity for communication, through the connection of remote vertices, ensuring a rapid transfer of information throughout the network; ii) local groupings, or close neighbor relations, which creates a good capacity for absorption of adverse impacts in the fringes of the network, giving robustness to the system as a whole. It is, therefore, a small and at the same time clustered world, where communication and robustness arise as derivative properties.

Albert-László Barabási (2002) started from the results of Watts and Strogatz and went a step further, trying to understand the evolutionary properties of small world models in competitive environments. In traditional models, the most connected members are those that have appeared first, their links stem from a precedence order. The first ones to appear have a clear advantage. In the real world, this is not necessarily true. Empirical observation shows that some companies that have arrived later may dominate the network. Thus Barabási assumed a property to capture the fitness of vertices, i.e. their ability to attract connections. Under this "magnetism of influence", the dynamics of network growth showed that the number of connections of each vertex is not constant. On the contrary, a few vertices (called hubs) end up attracting or concentrating many edges, while many other vertices are left with very few connections.

Barabási verified that the frequency distribution of these connections has a fat tail, that is, a distribution usually described as a power law. This means that there are a greater number of vertices at the extremes, i.e. with many more and/or many less connections than would be expected if the connections followed a Gaussian distribution. A somewhat surprising result for researchers, who expected a behavior compatible with ordinary systems found in nature – such as the height of individuals in a population – where quantities usually follow a bell curve. Without the "normal" boundaries, these small world models came to be known as scale-invariant or scale-free.

What is interesting in this episode is that power-law-type distributions typically describe physical systems in a state of transition. That is, they arise in nature as unmistakable evidence that complex systems are self-organizing, moving from chaos to order. This discovery opened up a new perspective for network theory, bringing coherence and allowing for previously unsuspected parallels.

The models began to express a frequent form in network environments, namely, the presence of hubs, and the rich-get-richer phenomenon. The phenomenon presents itself as a power law, as verified in several scale-free networks of the real world, for example: in the web itself, in the way computers are physically connected to the Internet, in the way species are found in an ecosystem's food chain, in the way companies in the same industry form partnerships, in the way the boards of American companies, and actors in Hollywood movies, are distributed, or even in the way proteins interact in the cellular metabolism of various living organisms (Barabási 2003)[1].

Such is their regularity that it has been speculated that this type of scale-free network reflects the "topology of our choices" (Sato, 2004). It seems that when individuals begin to interact with each other and establish connections, the classic normal distribution disappears, making room for another logic that prevails in the social order: scale-free power law distributions.

In many competitive network environments, such as in business or the ecosystem, we may observe that

1 *As an illustration and curiosity, knowledge about the scale-free networks has implications for the understanding of phenomena such as the spread of computer viruses or infectious diseases, with important practical implications for public health professionals and epidemiologists. Due to their high connectivity, empirical work has shown that the threshold for population contagion in the scale-free models is zero (Barabási 2003). That is, when a virus encounters the hubs in a scale-free network, the ensuing epidemic is practically immediate. Measles vaccinations, for example, need to reach 90% of the population to be effective. Instead of traditional policies of random immunizations, a more effective method would be to direct the campaign to reach, as soon as possible, the most connected individuals (hubs).*

a company or species ends up completely dominating its niche/segment. It is the so-called winner-takes-all effect. Here we leave the realm of power laws and small world models to face a different reality. And curiously, the theoretical insight behind the winner-takes-all phenomenon is borrowed from no other than quantum physics – her again!

To make a long story short, in 1925, Einstein predicted that if a gas were sufficiently cooled, a significant fraction of its particles would rest at their lowest possible energy level. At this critical temperature, the particles would constitute a new material, called the Bose-Einstein condensate. Indeed, the empirical verification of yet another genius conjecture of Einstein occurred 70 years later, and the two researchers who managed to freeze some rubidium atoms in their experiment were deemed worthy of the Nobel Prize in physics[2].

The remote link from this idea to the reality of connectivity we are describing was constructed from a "simple" mathematical transformation, where the energy of the gas particles in the original physical model was used as the fitness of vertices in the network model. The addition of new connections in the network simulated the inclusion of new gas particles; the new vertices worked as if they were new energies in the system. The correspondence between the experiments was accurate and the result surprising: just as in the Bose-Einstein condensate, where all the particles gathered at the lower energy level, leaving the other energy levels empty, in some networks, the most adapted individuals could theoretically grasp all of the connections, leaving nothing to others. The parallel with the physical experiment underlies a theoretical explanation for the winner-takes-all phenomenon in network environments. An incredible link between the dynamics of physical systems and the properties of network topologies.

We urge our readers to be patient and allow us to keep these notes in the main body of the Report, and not to refer them to the footnotes, because they are more than mere intellectual curiosities. As we recalled in the previous Report, this stubborn habit we have of incessantly inquiring about the roots of phenomena comes from the daily exercise of our research work. *Why* and *how* are our favorite tools for work. Well, in this case, the effects are obvious and noticeable by all: accelerated business disruption with the emergence of extremely dominant players, such as Amazon, Google, Facebook, Apple, Airbnb, and Uber, among others.

What these insights from network theory are proposing, as an explanatory foundation, is that these network structures have similar properties to the physical systems in their transition states: they behave dynamically, they are in a continuous movement in the direction of more order (characterized by higher inequality), and are eventually able to reach extreme asymmetries where even a single participant may capture the entire market. Here, then, are the explanations for the rich-get-richer and winner-takes-all phenomena so typical of this new business model that will be addressed in our next Report.

Another important message brought by this theoretical framework lies in the fact that the scale-free network topology is a good model for growth, engenders excellent connectivity, and, at the same time, robustness. In addition, it usually arises early on in the formation of a network. Thus, entrepreneurs who are developing network-based businesses, such as technology startups, or even any business engaging in numerous and important interactions with the outside world, such as strategic alliances, licenses, distribution, or retailing, should pursue strategies that embody this kind of structure. That is, they should attempt to establish and cultivate hubs, and simultaneously develop vertices that communicate in consistent ways. The hubs in scale-free networks are like the central nervous system, the tickets for success. Hence we find that, for example, in marketplaces, establishing

2 *A group led by Eric Cornell and Carl Weiman, of the National Institute of Standards Boulder, in Colorado, was awarded the 2001 Nobel Prize for Physics.*

a critical mass of high-performing, recurring and well-ranked sellers becomes essential to sustaining the business. Likewise, without the proper connections between vertices, merger strategies, for example, can go the wrong way. In the AOL/Time-Warner episode this was very clear. AOL provided internet access and content, and Time-Warner was an entertainment and publishing company. Because their business segments (vertices) never connected, the expected synergies never materialized.

Rich-get-richer and winner-takes-all effects lead, unsurprisingly, to market dominance. It is not rare to find quasi monopolistic technology companies. In the next Report, we will describe in further detail a successful business model in this environment. For now, it is worth noting that this reality has been raising concerns among regulators. Although it is no news – Microsoft has been battling with antitrust officials since the 1990s, Intel has been fined by the European Community for a billion Euros in 2009, and Google has faced its share of scrutiny since 2007 (in Australia) – animosities are on the rise. In June 2017, antitrust officials of the European Union charged Google the highest fine in their history, at 2.4 billion Euros, accusing the company of "abusing its market dominance" by promoting its own price comparison services in its search results in detriment of its competitors'. The Commission is also accusing Google of harming its rivals with specific ways it makes use of the Android operating system.

Regulatory discussions go a long way. In Europe, the question of competitive "dominance" has always bothered regulators more. In the United States, authorities are less sensitive to the claims of competitors who feel they are unjustly harmed. Large technology companies end up competing against each other and there is always room for a new entrant when the ultimate goal is to deliver the best customer experience. It turns out that algorithms have also shown an enormous ability to prioritize consumer preferences and direct choices. If, on the one hand, a possible break up of big tech monopoly in the manner of Telecoms (AT&T) still seems remote, on the other hand, concerns about the remedies that regulators may impose on technology companies are on investors' radars. Security issues, property rights, and tax planning have all been subjects of greater scrutiny. Like investors, regulators also need to update their manuals in order to understand the new dynamics of competition in the digital environment.

Networks are forms of decentralized organizations and their power comes from both the variety and the intensity of their connections. Networks have their own dynamics. As they expand, more connections are formed and curious things begin to happen. As the number of connections grows arithmetically (n), the value of the network grows exponentially[3] (2^n). The arrival of new members improves the experience of the other members. It is a generous mathematics where what is taken out acquires more value than what is put in. We are in the realm of increasing returns, an exception to the rules of traditional economics, where diminishing returns prevail. The gears of the traditional economy are based on scarcity. Increases in supply eventually face higher production costs, and additional demands find disutility in consumption. More is worse. But the logic of networks is diverse. With each new member, the value of the network increases. And the greater the value of the network, the more new members are attracted to it, forming a mechanism of self-reinforcement that compounds its impacts. It is the logic of abundance, following the logic of opportunity. As more connections are established, the more opportunities are conceptually proliferating, paving the way for unintended consequences. In this paradigm of abundance, the slopes of the supply and demand curves are inverted. The more a resource is used, the more demand there is for it. The more available the good is, the more value it brings. Since digital products can be replicated at zero or near zero cost, the

3 *In the next Report, when we deal with more practical aspects of networks, we will qualify this statement.*

more valuable it becomes, the cheaper it gets. The equilibrium, if it is to be reached, will be at a point much further from the ordinate axes and closer to the abscissa, that is, with low prices and high volumes.

The traditional economy also knows about the value of self-reinforcement through the positive effects of economies of scale and scope. But in this case, the dynamics are linear. The scale of production increases, and average costs fall in a gradual and fixed rate. In networks, the value grows exponentially. Small initial stimuli are amplified as they travel through the circuitry of connections, generating results with compounding effects. The larger the network, the greater the effect of the amplifications. In the exponential logic of 2^n, the larger n is, the more spectacular the marginal participation of (n + 1).

Conventional economics is organized around production. It is the physical limitations of the production process that determine the physical characteristics of consumer products and that reach end markets. In addition to producing a product, you also have to put it in front of the consumer and convince him to purchase it. Location, distribution channels, and proper marketing are key elements in this arrangement. It is a supply-side world view. In the digital environment, the marginal costs of production and distribution are negligible, the importance of physical proximity collapses, at the same time that the consumer market is potentially mistaken by the aggregate demand, or the total disposable income. A consumer in a physical t-shirt shop will be willing to spend a certain percentage of his or her budget on that shop. The consumer with a credit card in front of a computer can be offered any merchandise. In theory, all your consumption (and savings) needs could be met. In this world, the logic of demand prevails.

In the paradigm of supply, efficiency and economies of scale in production are fundamental. The capacity of reducing average costs as production increases is an important competitive advantage. Competitors are known and well-defined entities, and the greater the control of industry supply, access to strategic inputs, distribution channels, and infrastructure, the more consolidated is the advantage. The competitive environment is relatively simpler. Production takes place within the linear logic of the "supply chain" model, where inputs are combined and manipulated until they are transformed into final products with perfectly defined properties and uses. Under this architecture, the name of the game is efficiency, scale gains, and the construction of competitive protections in order to preserve (lock-in) the advantages acquired. Once this advantageous position is reached, the idea is to try to erect more barriers and sustain them. In this case, the survival strategy is to maintain the status quo. Once the stable and predictable horizon is paved, strategic planning emerges as an appropriate management tool.

In the environment of network connectivity, other ingredients prevail in the economic logic. Network effects are critical, producing the so-called economies of scale on the demand side. Positive network effects occur when the value of a good or service grows as more users adopt it, a few examples include telephones, operating systems, and social networks. They may have a high fixed development cost, but they certainly have low marginal distribution costs, and practically zero marginal costs in the case of digital components. Therefore, after reaching a critical mass, the value creation is tremendous. Where there are positive network effects, growth leads to market expansion.

In some cases, the fixed costs of development are also reduced, particularly in the digital environment. Combined with insignificant marginal costs and enormous distribution capacity, the threshold of significance – the period before the tipping point, the point from which growth/innovation should be considered relevant – also becomes dramatically lower than in the traditional economy (Kelly 1998). Understanding the development of new businesses at this stage becomes very difficult and at the same time very important. This also explains the common feeling we get in this digital environment, where competitors seem to appear "all of a sudden". In fact, it is a combination of the lower and earlier threshold for the level of significance, with the reality of exponential growth. Of course, this has important repercussions for companies and investors, as we will see in the next Report.

The network effects can be direct, when the value grows only for the user of the good (telephony, social networks), or indirect, when the marginal value grows for both the consumer and the producer of the good (software, credit cards, operating systems, stock exchanges, marketplaces). If in the traditional economy gains in scale result from the fall in the average cost of production (supply), in environments with positive network externalities, where the value of the good increases with the number of users, the gains in scale translate into growth in average revenue per user (demand).

Network effects act as accelerators, allowing for more rapid diffusion, increasing the likelihood that each person contacted by an existing user/member also adopts the product. That is, the value of the network as a whole increases as the additional members connect sequentially.

Network effects create positive feedbacks producing an environment of increasing returns that tend to amplify the differences between competitors. It is a different dynamic from the traditional "physical" environment, where from one point onwards growth inevitably leads to loss of efficiency and diminishing returns. In the digital world, the greater the advantage of a given company, the more it tends to amplify, mainly due to network effects and the dependence on a given technology, which presents a relatively high learning (and therefore switching) cost. Hence the goal of several companies in seeking to establish an advantage early on, to capture the benefits of winner-takes-all or almost-all effects.

Another important difference is that the economies of scale of traditional industries usually stem from the isolated efforts of individual companies, from the logic of seeking preeminence among their peers. The expertise is kept within company walls as a strategy of survival and dominance in a logic of competition confined to a single industry. In the network environment, increasing returns are usually generated and distributed throughout the system, producing important positive externalities. External agents also share in the processes of innovation and value creation. While there may be unequal benefits to some, the overall benefits become accessible to the entire ecosystem of relationships around the network.

A typical feature of this process of digital innovation is that it feeds off itself, producing positive network externalities. Digital innovation presupposes access to digital technology. The higher the technology penetration, the higher the innovation. And the higher the innovation the lower the learning costs. Thus, the lower the barriers to entry for potential future innovators, making technology even more available. As a corollary, potential competition increases brutally. By democratizing the process of innovation, digital technology produces a much more interesting world for the consumer and a much more challenging one for companies.

The above arguments may seem contradictory, but they are not. They just reflect the diversity that characterizes the digital environment. On the one hand, technologies can in fact generate genuine competitive barriers by, for example, producing high switching costs, such as with operating systems, where users accustomed to a certain standard may become reluctant to experiment with alternatives. On the other hand, technologies can greatly facilitate the life and bargaining power of the consumer. In the case of e-commerce, for example, the consumer is benefited by the great ease of online price comparison, and may eventually feel more comfortable to move between different marketplaces.

In the same way, as mentioned above, in some situations, the early adopter can establish definitive advantages, dominating the market. On the other hand there are examples – as we will see in the next Report – where late adopters succeed in offering a superior customer/consumer experience and end up displacing incumbents.

The power of microprocessors and traffic capacity we described in the previous Report greatly expanded the reach of the networking environment, bringing digital connectivity to analog reality. With chips, sensors, and software, traditional physical products now incorporate digital attributes. They stopped defining themselves as static and isolated realities, and started to partake in a dynamic network environment. We are in the world of the internet of things (IoT), or the internet of everything.

Nike+ is an application that gives tennis shoe users a wealth of features, such as performance tracking, training suggestions, the ability to connect with experts, and the sharing of results and experiences. John Deere, a traditional producer of agricultural vehicles, offers a portfolio of technological solutions coupled with its equipment, ranging from the nutritional analysis of soil, to the identification of harvested material, to complete fleet management, where they measure the fuel consumption pattern and the maintenance status of each machine. Amazon Alexa/Echo performs numerous voice-activated functions, such as making phone calls, controlling the TV, playing music, setting alarms, generating real-time information, triggering appliances, and so forth. Insurance companies are installing microchips in vehicles to measure the acceleration and braking levels that may eventually accuse the driver's driving profile, and thus better price insurance premium.

In healthcare, remote and intermittent patient monitoring dramatically reduces hospitalization costs and the need for interventions. In homes, gains in energy efficiency are expected, as well as savings with the automation of household tasks, and greater comfort and security, such as through smart doorbells and locks that allow for better monitoring and access control through mobile devices. In retail, efficiency gains are already coming from multiple fronts such as checkout automation, real-time promotions in stores, inventory management, and smart CRM systems. In industry, there is a whole chapter of efficiency improvement in production, replacing human decision by sensors in the calibration of the equipment, besides the possibility of real time monitoring of the entire production flow. Results also come from improved preventive maintenance and inventory optimization. Even in more traditional industries such as manufacturing, for example, estimates of productivity improvement are considerable. At the largest global steel conference in the United States this year, companies were talking about gaining up to 30% on digitization in the production process.

Through a comprehensive study, McKinsey (2015a) attempted to estimate the potential gains from IoT, that is, from the reality of interconnecting comprehensive physical objects in various environments (residences, offices, factories, farms, hospitals, cities). The value generated by the internet of things would derive basically from an increase in the productivity of capital and labor, time savings, better management of existing assets, and reduction of diseases, accidents

Dynamo Cougar x IBX x Ibovespa Performance up to November 2017 (in R$)

Period	Dynamo Cougar	IBX	Ibovespa
60 months	86.2%	35.2%	18.1%
36 months	64.5%	43.6%	43.9%
24 months	45.0%	57.7%	59.5%
12 months	22.9%	16.9%	16.3%
Year to date	22.7%	19.9%	19.5%

NAV/Share on Novenber 31 = R$ 751.0466257

DYNAMO COUGAR x IBOVESPA
(Performance – Percentage Change in US$ dollars)

Period	DYNAMO COUGAR* Year	DYNAMO COUGAR* Since Sep 1, 1993	IBOVESPA** Year	IBOVESPA** Since Sep 1, 1993
1993	38.8%	38.8%	7.7%	7.7%
1994	245.6%	379.5%	62.6%	75.1%
1995	-3.6%	362.2%	-14.0%	50.5%
1996	53.6%	609.8%	53.2%	130.6%
1997	-6.2%	565.5%	34.7%	210.6%
1998	-19.1%	438.1%	-38.5%	91.0%
1999	104.6%	1,001.2%	70.2%	224.9%
2000	3.0%	1,034.5%	-18.3%	165.4%
2001	-6.4%	962.4%	-25.0%	99.0%
2002	-7.9%	878.9%	-45.5%	8.5%
2003	93.9%	1,798.5%	141.3%	161.8%
2004	64.4%	3,020.2%	28.2%	235.7%
2005	41.2%	4,305.5%	44.8%	386.1%
2006	49.8%	6,498.3%	45.5%	607.5%
2007	59.7%	10,436.6%	73.4%	1,126.8%
2008	-47.1%	5,470.1%	-55.4%	446.5%
2009	143.7%	13,472.6%	145.2%	1,239.9%
2010	28.1%	17,282.0%	5.6%	1,331.8%
2011	-4.4%	16,514.5%	-27.3%	929.1%
2012	14.0%	18,844.6%	-1.4%	914.5%
2013	-7.3%	17,456.8%	-26.3%	647.9%
2014	-6.0%	16,401.5%	-14.4%	540.4%
2015	-23.3%	12,560.8%	-41.0%	277.6%
2016	42.4%	17,926.4%	66.5%	528.6%

2017	DYNAMO COUGAR* Month	DYNAMO COUGAR* Year	IBOVESPA** Month	IBOVESPA** Year
JAN	10.2%	10.2%	11.9%	11.9%
FEV	3.9%	14.5%	4.0%	16.4%
MAR	-2.1%	12.0%	-4.6%	11.0%
ABR	1.0%	13.2%	-0.3%	10.7%
MAI	-1.3%	11.8%	-5.5%	4.6%
JUN	-1.3%	10.3%	-1.7%	2.9%
JUL	9.3%	20.5%	10.7%	13.9%
AGO	3.5%	24.7%	6.9%	21.8%
SET	3.2%	28.7%	4.2%	26.9%
OUT	-5.4%	21.8%	-3.3%	22.7%
NOV	0.7%	22.6%	-2.7%	19.4%

Average Net Asset Value for Dynamo Cougar
(Last 12 months): R$ 2,935,522,360

(*) The Dynamo Cougar Fund figures are audited by Price Waterhouse and Coopers and returns net of all costs and fees, except for Adjustment of Performance Fee, if due. (**) Ibovespa closing.

and deaths. By the consultant's calculations, the gains could reach an upper bound of $11 trillion per year, or about 11% of global GDP in 2025.

Even with all the caveats that these types of estimates invite, its order of magnitude is impressive. The potential for wealth generation in the digital environment suggests a new level of growth for countries that go down this path. It is a curious result. As we have seen, the logic of the traditional economy of efficiency and productivity. In networks, the main concern is that of connectivity. The goal is to make more numerous and dense connections as possible. In the environment of increasing returns, the value is more in capturing the enormous growth potential than in optimizing costs. It seems that, when technology and connectivity invade the traditional economy, they allow for new levels of gains in the productive process, further reinforcing the traditional logic of efficiency.

Having laid the foundations that give substance to the digital world (technology and connectivity), in the next Report we describe a business model that, by combining these two particular elements, has been promoting great changes in the business environment.

Rio de Janeiro, December 27, 2017.

Please visit our website if you would like to compare the performance of Dynamo funds to other indices:

www.dynamo.com.br