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ICT as a Technological and Machinery System: implications for competitive dynamics

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Abstract

Divided into two parts, this paper aims at two interrelated objectives. The first part aims to outline the conceptual aspects of information and communication technologies (ICT) as a technological system incorporated in a global machinery system. To achieve this goal, I analyze the three central technologies of this system and their interrelationships, that is, semiconductors, mobile telecommunications systems, especially 5G, and artificial intelligence. These technologies are posited as a key technological system underpinning different waves of modernization. Such system is constituted by a stack of technologies that coevolve and engenders a historical process forming a global machinery system. The paper's second part aims to analyze the implications arising from this conceptualization for competition between the technological great powers and their tech companies, particularly in the cases of the U.S. and China.

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Introduction

The digitalization of social life and the economy, along with a series of major unfoldings, such as the rise of platforms and the development of automation based on artificial intelligence, have given rise to important transformations in the dynamics and competitive strategies of technology corporations and the great powers. Digital technologies became the core of the national projects and industrial policies of manufacturing restructuring, while technological rivalry between major powers has intensified. These transformations aroused numerous debates among academics and the society at large, with the emergence of several exuberant theses about the nature of the economic system, labor and the geopolitical rivalry in the era of digitalization. Some of these theses have been recurrent in the interpretation of the current dynamics of digital transformation, having even become a common place in academic, journalistic, and industrial writings.

In particular, the analytical treatment of data and economic competition has provoked radical reformulations at the theoretical and analytical levels. From the point of view of the economic system, there are those who, based on the business model of large technological platforms, particularly those of propaganda (e.g. Facebook, Google), postulate the emergence of a new capitalism or, even, a tendency to establish a new mode of production, the techno-feudal. Competition for data – and not for profits – is what anchors Zuboff's (2019) formulation on Surveillance Capitalism, in which capitalists seek behavioral surplus instead of surplus conceived in terms of value (Morozov, 2019), as in classical political economy and Marx. Also emphasizing the capture of and competition for data by large platforms, Durand (2020) elevates these dynamics as central to his techno-feudal hypothesis, being identified as the process of "conquest of digital fiefdoms". In this hypothesis, there is an explicit link between the idea of "conquest" with the notion that data is the new oil, comparable, therefore, to a natural resource amenable to extraction.

In contrast, there are those for whom data is the fruit of human labor, and any human activity that results in data creation must be understood as work. In his "playbour" thesis, performed by “prosumers", Christian Fuchs (2014) understands data as coming from the immediate work of users of digital devices and the Internet. Digitally mediated human activities, hence, data producing activities, become, for the author, a labor process, in general, done free of charge, giving genesis to what he calls "playbour" – that is, the idea that even when we are only in leisure time, we are working free of charge in the production of data, a theoretical procedure that voids the meaning of the category labor and its constitution in relation to capital.

The substance of this interpretation can be found in several authors such as Dyer-Witheford and Matviyenko (2019, p. 86), who embrace its logic extension: "Today, not only chatting, liking, sharing, gaming, viewing, and other fun has become work but also walking, breathing, sleeping, and doing nothing, as these activities are submitted to technological surveillance". Thus, labor becomes, for this branch of academic literature, the fact that people are subjected to digital surveillance, which applies at the same time, it should be noted, for all classes as defined by the Classical English Political Economy and Marx.

It is not only in the realm of political economy that the processes of digitalization and automation based on artificial intelligence have given rise to theoretical and analytical transformations. The same can be said in the field of analysis of interstate relations. The deepening of digitalization in a context of increased competition between China and the U.S. has led several analysts to predict the emergence of a "digital divide", with two compartmentalized ICT systems, headed by each of these great powers, often referring to a new Cold War (Kaplan, 2019; Rachman, 2020; Smith, 2020; Yao, 2021) and the existence of two economic blocs waging geopolitical disputes, largely as a technological race.[3]

With so many predictions and theoretical transformations that point to fundamental ruptures, often based on reformulations of past modes of production and configurations of the international system, it is necessary to take a step back and seek to understand the productive structure and technological dynamics under which the said competitive processes between capitals and States are based. That is, the apprehension of the strategies and competitive dynamics of large technology companies and technological great powers presupposes the specification of the general characteristics of the key technologies that make up this technological system, their interrelations, and their differentiated dynamics diffusion, considering that "technology discloses man’s mode of dealing with Nature, the process of production by which he sustains his life, and thereby also lays bare the mode of formation of his social relations, and of the mental conceptions that flow from them " (Marx, [1867] 2017, p. 330).

By clarifying these key factors, the material elements that provide the limits of possibilities for the unfolding of the real, although we cannot predict the exact paths of the

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[3] "As several critics have observed, applying the Cold War metaphor to these tensions is deceptive (Ciuta and Klinke 2010; Sakwa 2013; Budraitskis 2014). At stake in the old Cold War were contending modes of production and opposed models of society, organized respectively around markets and planning—a compelling binary whose hold over both popular and elite imaginations was scarcely diminished by the actual corruption or occasional collusion of the antagonists. In the New Cold War, no such epic binaries are in play; all protagonists are participants in the world market, differentiated at best along a spectrum that runs from free-market neoliberalism to variants of state capitalism." (Dyer-Witheford and Matviyenko, 2019, p. 21).

world economy and the interstate system, which are the fruit of multiple determinations and surrounded by contingencies, we can at least account for the limitations and implausibility of some of these so compelling theses – as well as their conditions of possibility as interpretations of contemporaneity. In addition, such expedient enables us to establish some central axes and general trends underpinning the unfolding of the technological dispute between capitals and states, especially between China and the USA and their technology companies.

To this end, this paper is divided into eight other sections. Initially, the main characteristics of the three key technologies of such system will be addressed – namely semiconductors, mobile telecommunications infrastructure, particularly 5G, and "artificial intelligence" in the form of deep neural networks – in the context of two distinct ICT-based diffusion and modernization waves. Thus, section 1 addresses digitalization and networking, highlighting the progresses in semiconductors and the successive renewals of mobile telecommunications systems as drivers of the first wave of ICT-based modernization, while section 2 addresses the latest technology, artificial intelligence or machine learning and its limits. Considering the contemporary diffusion of ICT as a new wave of modernization, section 3 is dedicated to this second wave, while postulating 5G as its appropriate material basis. These three technologies, in an integrated way, are the object of section 4, which emphasizes their development as a technological system historically constituted from a stacking of technologies submitted to coevolution. Section 5 addresses both the incorporation of this technological system into the modern machinery system and data production. From these conceptual elaborations, sections 6 and 7 discuss important trends and implications of the key ICT system and the modern global machinery system for competitive dynamics between large technology companies and the technological great powers, particularly in the face of the Sino-American rivalry. The last section is intended for final considerations.

PART I: CONCEPTUAL ASPECTS OF ICT

1. Digitalization and networking

The dissemination of ICT in recent decades had both as presupposition and consequence the rapid technical progress in its production base, particularly in the branches producing capital goods and high-tech inputs, in which are located semiconductors and semiconductor manufacturing equipment (Majerowicz and Medeiros, 2018; Majerowicz, 2020). Based on drastic reductions in production costs, along with increased capacity and miniaturization of its fundamental inputs, this accelerated diffusion had its first wave in the escalation of consumption of mixed-use electronic devices (unproductive and productive consumption), especially computers and smartphones, and the expansion of Internet access, accompanied by successive renovations of telecommunication infrastructure.

The emergence of the first generation of wireless telecommunications systems (1G) in the 1970s – made possible by the emergence of microprocessor chips (Ssemboga and Restrepo, 2018) – and its evolution were fundamental conditions and mainstay for ICT-based modernization waves. While the first generation was analog, enabling voice transmission, from the second generation (2G) onwards, implemented throughout the 1980s and 1990s, mobile networks became digital (Ssemboga and Restrepo, 2018), simultaneously to the growing privatization of the digital economy (Dyer-Witheford and Matviyenko, 2019). The successive digital generations have significantly increased connection speed, with lower costs, enabling different services and business models. In 2G, only text messages and applications were viable, while 3G, implemented in the 2000s, made navigation in internet domains and multimedia applications possible, but with very low capacity to support videos, which became effectively supported by 4G (Ssemboga and Restrepo, 2018). Perhaps even more important than the ability to stream videos, it was in 4G, implemented in the 2010s, that the main method of Internet access became mobile broadband, supported by the rapid and massive spread of smartphones.

In the 1970s and 1980s, the diffusion of digitalization was more or less restricted to the use of computers and dedicated networks in military applications, research institutions, the public sector, international agencies, and companies – both in the financial and productive sectors, enabling, for example, the creation of the SWIFT in 1973 (Scott and Zachariadis, 2013), the restructuring of white-collar occupations (Huws, 2014) and the emergence of global value chains in manufacturing –, while the significant expansion of the Internet occurred only from the 1990s onwards. It was only in the 1990s and 2000s that digitalization and Internet access gained traction among consumers in general, manifested in the first wave of modernization based on computers and smartphones. In the 2010s, these processes led to several substantial developments – namely, the process of plataformization of the economy and sociability; the rise of Big Data and deep neural networks; the starting-up of the digitalization and networking of objects in general – especially surveillance cameras and the widespread implementation of urban and home sensors –; and the deepening of diffusion in manufacturing production processes. These developments have put in motion a second wave of modernization based on ICT.

Thus, in recent years, the process of digitalization and networking has been rapidly extrapolating its initial scope – focused on devices whose primary functions were eminently computing and communication –, taking the form of embedded diffusion, that is, whose characteristic is to provide communication and computing capabilities, even if through the cloud, to objects in general, from machines and equipment to traditional consumer goods and infrastructures, which have other primary functions. Although this process is not genuinely new – as it is enough to recognize the relatively long existence of computerized industrial control systems and machinery and equipment with electronic modules used in manufacturing production processes (Gutierrez and Leal, 2004) –; what is postulated is, in a certain way, a universalization of this process, with its rapid intensification, extending even to the most trivial goods. This ubiquitous computing project is well translated by industrial jargons such as the Internet of Things (Ogonda, 2017; ITU, 2012; McKinsey Global Institute, 2015) and the Internet of Everything (Cisco *apud* Miraz et al., 2015; Qualcomm *apud* Miraz et al., 2015).

This built-in diffusion is, in the first instance, a question of ingraining the building blocks of ICT capabilities, semiconductors, in objects and structures. Therefore, the digitalization of the physical world consists in the implementation of semiconductors, both sensors and integrated circuits (chips). Sensors transform analog signals into digital ones – enabling them to perceive the environment and generate data about their position and status –, while chips store, process and modulate/demodulate into radio frequency signals that are communicated by antennas and connected to mobile telecommunication[4] infrastructure, enabling the use of networked data and cloud computing (Majerowicz, 2020; Majerowicz and Medeiros, 2018). From the point of view of communication, these digitized elements can be connected to the Internet, as the idea of the Internet of Things translates, or to dedicated[5] networks, in addition to forming cyber-physical systems, particularly in manufacturing processes and critical infrastructures.[6]

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[4] They connect "to modems in advanced base stations and ultimately link to routers that form larger networks" (Lewis, 2018, p. 6)

[5] Dedicated networks are implemented, for example, when seeking to preserve industrial secrets in sophisticated manufacturing processes or reduce the vulnerability of critical production units such as nuclear plants.

[6] Regardless of the network being dedicated or not, cyber-physical systems encompass a virtual counterpart of machines and objects to simulate the operations of physical elements. Instead of merely monitoring objects through sensors, cyber-physical systems have further emphasis on control, acting upon the environment, being especially used in critical infrastructure: "CPSs [cyber-physical systems] perform automated or partially automated control of physical equipment in manufacturing and chemical plants, electric utilities, distribution and transportation systems and many other industries" " (Colbert, 2017, p. 41).

2. Artificial intelligence or machine learning

The maturation of the first wave of ICT diffusion was responsible for generating gigantic masses of data with a high degree of granularity, particularly for online activities and the geographical position of individuals through the Global Positioning System (GPS) accessed by smartphones – and, therefore, as Greenwald (2014) stresses, also for the recomposition of their trajectories. The emergence of Big Data for financial transactions, consumption, mobility, political preferences, and personal contact networks, among other activities and attributes, enabled the implementation of statistical techniques based on the identification and synthesis of patterns and correlations present in large masses of data through the intensive use of computational capacity (Pasquinelli and Joler, 2020; Katz, 2017; JASON, 2017). What is meant by artificial intelligence (AI) is, therefore, the application of these techniques to the large masses of data, enabling a certain type of partial or complete automation of various work processes and human activities.

Such statistical techniques, sometimes labeled as Big Data Analytics, sometimes labeled as machine learning, deep learning or artificial intelligence – "whose common denominator is the use of expensive computing power to analyze massive centralized[7] data" (Katz, 2017, p. 2) – have experienced important development and diffusion with deep neural networks.[8] Using as input large masses of data, in general, already labeled by people,[9] algorithms, by successive mathematical approximations with astronomical amounts of calculations, extract patterns present in these masses of data, that is, statistical models that describe them (JASON, 2017; Pasquinelli and Joler, 2020). In this process, dependent on the intensive use of computational power, that is, of integrated circuits or training chips: "The algorithm starts as a blank slate and, during the process called training, or 'learning from data', adjusts its parameters until it reaches a good representation of the input data."(Pasquinelli and Joler, 2020, p.8).

The product of the algorithm is, therefore, a statistical model representing the mass of data. The model is capable of recognizing the extracted pattern when faced with data not yet

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[7] " […] the "AI" label has been rebranded to promote a contested vision of world governance through big data. Major tech companies have played a key role in the rebranding, partly by hiring academics that work on big data (which has been effectively relabeled "AI") and helping to create the sense that super-human AI is imminent. However, I argue that the latest AI systems are premised on an old behaviorist view of intelligence that's far from encompassing human thought. In practice, the confusion around AI's capacities serves as a pretext for imposing more metrics upon human endeavors and advancing traditional neoliberal policies." (Katz, 2017, p.1)

[8] For a detailed explanation of deep neural networks, see JASON (2017).

[9] Labeled data are those previously categorized by people to be used in the training process of AI algorithms. This labeling is done both free of charge by Internet users and as paid labor by workers on platforms and employees in labeling "factories."

known, but which can be described approximately by the same function, applying the label associated with the recognized pattern. For Pasquinelli (2019), the algorithm is therefore an information compression machine. The statistical model that results from compression is a simple software that performs pattern recognition (classification) or inference; it can be embedded, for example, in vehicles, security cameras, and telecommunication equipment, through inference chips, which are simple and inexpensive when compared to training chips. Finally, the model can also be applied to generate patterns, through interpolations and extrapolations, to make predictions based on the patterns previously identified and synthesized by the model (Pasquinelli and Joler,2020).

However, some characteristics of these techniques must be emphasized to shed light upon the dynamics of their development and the technological rivalry, as well as their limitations, which make them more susceptible and appropriate to certain types of applications to the detriment of others. Notably, deep neural networks have developed as a set of procedures, which, once implemented, produce statistical models that roughly describe the masses of data, but which one does not know exactly how[10]. It is not even known the amount of data that would be required for proper training, so one follows the practical wisdom that "there's no data like more data" (Lee, 2018). Thus, it is necessary to generate large masses of data specific to each type of activity for the training of algorithms[11], and those activities generating a small volume of data, in general, are not susceptible to the application of such techniques. Even more importantly, what happens in training is described as a "black box", and the problem of explainable artificial intelligence (XAI) has been a limiting factor for certain applications, particularly military critical missions (JASON, 2017; Xu et al. 2019; Congressional Research Service, 2020).

Despite these limitations and a whole series of problems associated with this technology, which have been discussed by critical academic literature and civil society organizations – such

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[10] "Deep Learning [DL], based on DNNs [deep neural networks] trained on Big Data, is a tipping point in AI, evangelized by many fervent supporters. As a "dogma", DL has these beliefs: […] (iii) Desirability of training on Big Data with few hard-wired model assumptions. DL seeks to learn everything from the data, believing that "data is where truth lies". (iv) The strong belief that an approximate answer is good enough. When a solution works, use it and don't ask too many questions about *how* it works." (JASON, 2017, p.2)

[11] "The quality of training data is the most important factor affecting the so-called 'intelligence' that machine learning algorithms extract. […] Data is the first source of value and intelligence. Algorithms are second; they are the machines that compute such value and intelligence into a model. However, training data are never raw, independent and unbiased (they are already themselves 'algorithmic'). The carving, formatting and editing of training datasets is a laborious and delicate undertaking, which is probably more significant for the final results than the technical parameters that control the learning algorithm. The act of selecting one data source rather than another is the profound mark of human intervention into the domain of the 'artificial' minds". (Pasquinelli and Joler, 2020, p.5).

as "biases"[12], the proliferation of spurious correlations[13], and the inability to predict the genuinely new, projecting only the past[14] –, the diffusion of AI, especially deep neural networks, which began in the 2010s, has advanced with great strides. Coetaneous to the second wave of modernization, AI was initially applied to the voluminous masses of data derived from the first wave, while the scope of its application has been expanding as the second wave acquires momentum in different productive sectors, infrastructures, and activities, even though these processes are markedly uneven.

3. 5G, the telecommunication infrastructure of the new wave of digital modernization

This second wave, or the generic project of "digital intermediation of everything" (Morozov, 2018), finds in the new round of renewal of the global telecommunication infrastructure, 5G, an adequate material base. Developed and designed to sustain and enable the spread of such a wave, 5G is the first mobile telecommunication system intentionally designed to support massive amounts of devices, industrial systems, and mission-critical applications (Majerowicz, 2020). When fully implemented, 5G would provide *i*) an increase in connection speed such that it would make feasible, for example, the widespread use of virtual/augmented reality devices; *ii*) low latency and ultrareliable connection – in practical terms, connection is “instant” and without intermittences, enabling the development of mission-critical applications (e.g. self-driving vehicles, remote surgeries); and *iii*) massive machine-to-machine communications, enabling the massive support of low cost and low power devices connected to the network, fundamental for smart cities and the Internet of Things (Lee and Chau, 2017; Brake, 2018; Triolo and Allison,2018). Consequently, 5G is postulated as mainstay

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[12] One of the main debates on the implications and impacts of AI concerns its "biases", with emphasis on the automation and amplification of discrimination and oppression (Neil, 2016; Barocas and Selbst, 2016; Noble, 2018; Pasquinelli and Joler, 2020; Pasquinelli, 2019). Unlike the propagated neutrality of algorithms or their representation as "the truth", they can encode in the statistical model "biases" derived from the dataset used for training – since "the training dataset is a cultural construct, not just a technical one" (Pasquinelli and Joler, 2020, p. 5) – and biases derived from the algorithm itself.

[13] According to Smith (2020), the proliferation of large masses of data, the "deluge of data", engenders the exponential growth of possible patterns and correlations without meaning or spurious inscribed in the data vis-à-vis those really significant, so that Data Minning can prove to be a "fool's gold". Therefore, for Smith (2020a, p.1), "Models are more likely to be reliable if expert opinion is used in their specification, instead of viewing human expertise as an unhelpful constraint on knowledge discovery".

[14] The patterns identified in the historical data are the basis for algorithmic predictions through extrapolations, which entails the inability to identify and predict a "single anomaly", that is, to recognize the new and create really new projections, which, for Pasquinelli and Joler (2020, p. 16) lead to the "dictatorship of the past", which results from the "the application of a homogenous space-time view that restrains the possibility of a new historical event."

for the second wave – both in terms of scale and scope, as it enables applications not supported by 4G –, propelling the process of digitalization of the economy and society.

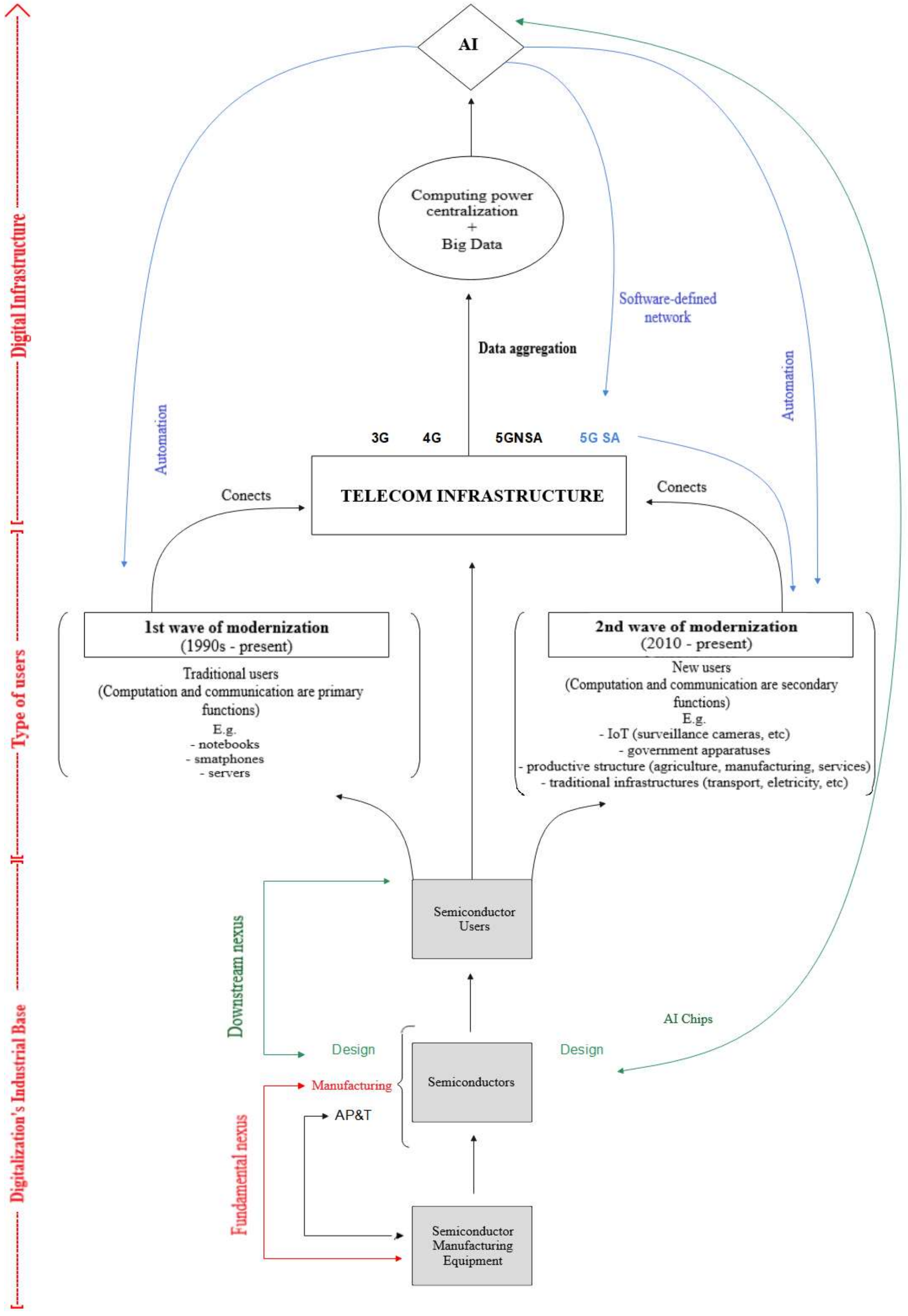
The novelties of 5G implementation relate primarily to the flexibility of the telecommunication infrastructure in coping with users' distinct needs through the slicing of the network in three large segments, providing the different services mentioned above. The slicing of the network is made possible by a combination of technologies – software-defined networks and network function virtualization –, which "allows traditional structures of a telecom network to be broken down into customizable elements that can be combined in different ways using software" (Lee and Chau, 2017, p.22). The complexity in defining these functions and allocating resources will be managed by AI (Triolo and Allison, 2018).

In practice, 5G will involve the renewal of all upstream layers (i.e. hardware) of the telecommunication system, because in addition to routers, switches and base stations that will be installed, there will be the vast expansion of fiberoptic cables, including those submarine, since the volume of data in transit will be substantially increased. Thus, the geography of the telecommunication network that will emerge with the implementation of 5G and its new international and intercontinental fiber optic cables, that is, the global architecture of the telecommunication infrastructure, will itself be reconstituted (Majerowicz, 2019).

4. ICT's key system: stacking and coevolution

As parts of a technological system and as digital infrastructures, the three key technologies under analysis must be understood, on the one hand, as a stack of technologies – which historically superpose one another and maintain necessary technical relationships – in which each layer has as technological presupposition and feasibility the development and implementation of the previous layers. On the other hand, once developed, the latest technological layers retroact on the technological development of the previous layers, engendering a process of coevolution and codetermination. Such coevolution, however, does not deny or suppress the technical preconditions of existence of the technologies at the top of the stack in relation to those at the basis, whose technical progress and its rhythm delimit the conditions of possibility and evolution of the upper layers and can propagate and impact the entire system. Moreover, the emergence of the technologies of the top layers and their coevolution, in general, depend on a certain advanced, if not massive, degree of diffusion of the previous technologies. In this sense, digitalization is a prerequisite for networking, while these are requirements for AI.

Figure 1. The stacking and coevolution of the key technologies in the ICT system



Source: Own elaboration

Note: "5GNSA" stands for 5G non-stand alone, a hybrid form of 4G (LTE) and 5G, which enables increased speed. "5GSA" stands for 5G stand alone, which also enables massive connection between machines and ultra-reliable and low latency connection. "AP&T" stands for assembly, packaging, and testing of semiconductors. "AI" stands for artificial intelligence.

Figure 1 synthetizes these relationships of stacking and coevolution of the key technologies in the ICT system. From data to the cloud, the entire ICT system rests on its foundation in the manufacturing industry, that is, semiconductors and semiconductor manufacturing equipment. As semiconductors are the building blocks of computing and communication capabilities, the rest of the technological system consists of semiconductor users.

The development of ICT and its dissemination were strongly based on technical progress in the production of semiconductor manufacturing equipment, especially in lithography machines. These machines make possible to manufacture integrated circuits with more and more transistors in the same space by reducing the size of the elements that can be printed, resulting in increasingly smaller and more powerful chips, while defining both the parameters for the manufacturing process and the design rules of integrated circuits (Majerowicz and Medeiros, 2018; Atta and Slusarczuk, 2012; Platzer, Sargent and Sutter, 2020). The most critical interaction of this system, or its fundamental nexus, consists of the productive, technical, and commercial relationships – including preferential access (Atta and Slusarczuk, 2012) and technical support/cooperation – between semiconductor manufacturing equipment firms and those in semiconductor manufacturing.

The interactions between semiconductor users and the semiconductor industry occur primarily through the demand for characteristics and specifications posed by users, which are incorporated into chips by the design segment of industry, the downstream nexus of the industrial base. As semiconductor-based applications increase in character and spread, as well as new demands for their use arise, semiconductor design adapts to these needs, engendering the proliferation and diversification of semiconductor types.

According to Majerowicz and Medeiros (2018), semiconductor users in the manufacturing industry (e.g. electronics industry), together with the semiconductor and semiconductor manufacturing equipment industries, constitute the modern industrial system. The first wave of modernization based on ICT was underpinned by the development and diffusion of electronic goods, whose primary functionalities are computing and communication – such as computers, smartphones, and tablets, but also switches, routers, and servers, necessary for the implementation of digital infrastructure. Erected upon these goods, the digital generations of wireless telecommunication systems were, in turn, fundamental to the very spread of electronic consumer goods, particularly smartphones.

By enabling this greater diffusion and mobile browsing on the Internet, 3G propelled the beginning of the production of large amounts of data, which proliferated, in fact, into Big Data with 4G. If, on the one hand, 4G enabled the pulverized production of large amounts of data due to the impulse it provided for the diffusion of electronics goods and the increased connection speed, on the other hand, it also became the material medium for the centralization of such data, which came into being as Big Data when in fact aggregated. The commercial pursuit for such data production and centralization, both by search engines and the emergence of platform business models, engendered the concentration of computational capacity in large Data Centers to make possible the storing and processing of data, eventually giving way for the emergence of cloud computing strategies and business services (Srnicek, 2021). It is in this marriage between data and computational capacity centralization (Katz, 2017; Srnicek, 2016, 2021) that deep neural networks became viable and proliferated as information compression techniques (Pasquinelli and Joler,2020) able to provide some kind of intelligibility to the astronomical amount of data and, from the patterns recognized, act back on the ICT system, automating it.

Therefore, the "intelligentization" or the implementation of AI-based automation has as technological presupposition the digitalization (i.e. the implementation of semiconductors) on a large scale for each specific type of activity and sector. Moreover, the networking provided by the telecommunication infrastructure and the concentration of computational capacity are also technological assumptions, since they enable, respectively, the constitution of Big Data through the aggregation of users' pulverized data and provide the computational structure at scale necessary for the storage of data and the training of algorithms. Given that for each type of activity to be "intelligentized" it is generally necessary to have Big Data of the same nature, initially AI was applied to Big Data arising from the first wave of modernization. With the diffusion of the second wave, propagating the production of Big Data to different productive branches and activities, AI also expands its scope of application.

However, if the first wave and 4G were necessary for the viability of AI, AI becomes a prerequisite for the second wave to gain momentum, since its implementation on the telecommunication network supports the slicing of the network (Triolo and Allison, 2018), enabling 5G, which, in turn, establishes itself as the appropriate infrastructure to sustain the second wave of digitalization, that is, the generalization of computing and networking embedded in the physical world, ubiquitous computing. In this sense, AI also becomes part of contemporary digital infrastructure – and it is even explicitly recognized as such by the Chinese government (Liu et al., 2020; XinhuaNet, 2020) – both by its direct implementation in the telecommunication system and its incorporation into productive, logistics, and urban structures as well as in state apparatuses, in the second wave of ICT-based modernization.

Finally, the development and proliferation of semiconductor users engenders transformations, through the downstream nexus of the industrial base, on semiconductor production itself: "Computing has long been the growth engine for the IC industry, but remarkable emerging applications in communication, consumer, automotive, and industrial/medical systems are fueling development of new complex, high-speed, and/or low-power ICs [integrated circuits]." (ICInsights, 2021a). Among these impacts of users on the production of chips, there is also the emergence of chips dedicated to AI applications, both for training and inference, propelling fierce competition for their development (Ernst, 2020). Moreover, just as semiconductors enabled computing and software development, whose maturation allowed their own incorporation into semiconductor design processes, with the emergence of "Electronic Design Automation tools" – which are the software tools used for chip design since the 1980s –, artificial intelligence itself has been incorporated into the integrated circuits' design stage (Mirhoseini et al. 2021). Therefore, these impacts of semiconductor users on semiconductor production are expressed both in what is produced, with the emergence of new types of semiconductors, as well as in how it is produced, with new and/or transformed means of production and, therefore, production processes.

5. The incorporation of the technological system into the global machinery system and the production of data

The integrated analysis of this key technological system of contemporary capitalism exposes to the naked eye the physical and productive aspects of data, the cloud, and artificial intelligence. This perspective contrasts with the image and common place assumed by data in academic literature, institutional discourses, and journalism, that is, the idea that "data is the new oil", and that, therefore, should be seen as a natural resource (Spijker, 2014; Toonders, 2014; The Economist, 2017; Bhageshpur, 2019; Durand, 2020). Rather than a natural resource, whose physical existence is independent of human action and its production as such, data do not simply exist, they are not fragments of existence and truth that orbit all around and are there to be extracted and captured. On the contrary, both raw data and Big Data are the product of the use of what, if we extrapolate the frontier of the firm as an analytical unit, we can understand as a vast machinery system with a surprising degree of socialization, whose historical development has made it eminently global.

This contemporary machinery system is composed by the industrial base of digitalization, the digital infrastructure, and electronic devices and objects with electronic modules coupled to the digital infrastructure. In this sense, this conception is consistent with the characterization made by Dyer-Witheford and Matviyenko (2019, p. 18) when analyzing cyberwarfare: "As such, it can be seen as part of the tendency of capital to automation and the expansion of constant capital, such that humans occupy increasingly interstitial and marginal positions within destructive, as well as productive, systems".

The global machinery system that incorporates the ICT technological system, on the one hand, negates the factory, by displacing it as the *locus par excellence* of its operation, both due to its character of infrastructure and the incorporation of mobile electronic devices to the subsistence wage, given their central role in the mediation and production of everyday life in modern societies. On the other hand, such a global machinery system reaffirms the factory and the factory system. From the stricter or more traditional point of view in designating the machinery system, as in Marx (2013) – what we have so far called the "industrial base of digitalization" –, it can be said that the "silicon machinery system", that is, the machines that produce semiconductors for the production of other machines, is what gives genesis, sustains, and conditions the pace of technical progress and development of the ICT machinery *system lato sensu*, this "global electronic monster". Hence, as will be seen later, the strategic character of the rivalry among the industrial and technological great powers for the mastery of this manufacturing system and the recent movement, which acquires the character of a competitive compulsion, of descent from the cloud to the industrial base by several US and Chinese Big Tech. The supposed post-industrial world has never depended so much on the shop floor.

And it is this movement that negates the factory itself as the *locus* par excellence of the machinery system while reaffirming it that points to the industrial revolution caused by the emergence and rise of the silicon machinery system, causing "a revolution in the general conditions of the social process of production, i.e., in the means of communication and of transport" (Marx, [1867], 2017, p. 267). By extrapolating the factory, the historical process and the contemporary project of universalization of the ICT machinery system, constituted from the alliance between large capitals and the states of the technological great powers, universalizes with it the despotic system of factory management, both through technical control (e.g. software, algorithms) – "when the machinery itself directs the labor process, imposing its rhythm" (Edwards, 1979 *apud* Castro and Guimarães, 1991, p. 44) – and the capitalist production and control of the infrastructure that enables the personal electronic device to transcend its individual machine status and integrate itself as a machinery system – (e.g. platform interfaces, the use of concentrated computational capacity in Data Centers, the connection to mobile base stations).

The project of "digital intermediation of everything" is, therefore, the project of expansion of this global machinery system over all aspects of the social and economic life, which enables with it the expansion of factory despotism – albeit in a contested way (Edwards, 1979 *apud* Castro and Guimarães, 1991) and with unintended consequences – and allows capital to convert once unproductive labor, such as those performed by taxi drivers and autonomous workers in the food sector, into productive labor due to the prerogative of remote and individualized control (Fontes, 2017; Huws, 2019). If, on the one hand, the universalization of the ICT machinery system tends to greatly broaden the sphere of productive labor, on the other hand, it makes this system indispensable for a multitude of productive and unproductive objectives – thus establishing distinct relationships with total capital and its accumulation. Moreover, at the same time that this universalization tends to incorporate under the category of productive labor low productivity activities previously carried out on the margins of capitalist accumulation by autonomous workers (Fontes, 2017; Huws, 2019), it tends to engender processes of partial and, in some instances, full automation, as it is massively diffused in new economic sectors and social spheres.

It is this ubiquity and the tensions associated with it vis-à-vis the accumulation of capital that pose serious analytical challenges to the treatment of data. Data are the product of human usage and the automated operation (e.g. industrial thermostats, urban sensors[15]) of this machinery system, which is incessantly used, renewed[16], and maintained by workers, in a more or less ancillary manner depending on the degree of automation of the activity. Data appear in this machinery system as its product, its input, and its means of production, depending on the circuit of capital accumulation and the positioning of this circuit in the global machinery system, that is, due to both its technological character of a coevolutionary stack and the fact of its complex and multiple relationships with individual capitals in the most distinct branches of

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[15] Obviously, there are sensors and other electronic devices that do not make up the contemporary global machinery system, because they are encapsulated from this, in general, for security reasons.

[16] The constant technological development, whether incremental or eminently new, implies that this machinery system is at all times being partially replaced and renewed for new technological incorporation (e.g. new smartphones of greater sophistication, more powerful photolithography machines, new generations of the telecommunication system).

activity. Moreover, data that are used by companies can be generated by human activities or the automated operation of the machinery system, may be paid or free of charge, may result from productive or unproductive labor, work or leisure, and even from activity or inactivity.

It is not a matter here, however, of exhausting the issue of data production and its relationship(s) with capital, but rather of emphasizing that the ubiquity of the contemporary machinery system expresses multiple and complex relationships with the accumulation of capital. Not every data that is a direct by-product of human activity can be unilaterally understood as labor – even if unpaid – as proposed by Fuchs (2014) in the prosumer and playbour theses, as well as not every relation established by capital and large technology companies in the process of data aggregation manifests itself and is carried out as a strategy of predation (i.e. redistribution of surplus-value among capitalists), as in Durand's technofeudalism (2020).

The economic and political rise and the visibility gained by the large digital platforms from their inroads in everyday life and our immediate experience, most notably the case of social networks, ends up dominating many of these analytical models and theses developed within the framework of an ICT Political Economy. Such platforms, because they are largely of directly unproductive use for their users, if not in leisure contexts, and because they are linked to marketing activities, have obliterated the productive aspect of both data and the contemporary machinery system – either when they are translated merely in terms of structures of predation and rent-seeking or when the analytical sense of productive labor itself is lost with its universalization to any and all digitally mediated and/or surveilled human activity.

Certainly, the existence of distributive processes among capitals and the strategies of appropriation of surplus value of these platforms are a relevant and fundamental aspect of contemporary capitalism. However, they are far from exhausting the set of corporate strategies pursued by platforms, let alone the relevant competitive dynamics and economic transformations that engender and emerge from the evolution and expansion of the modern machinery system. The race for data does not exhaust the fundamental terms of the competitive dynamics neither in capitalism *tout court* nor in this global machinery system.

Understanding the production of surplus-value and contemporary intercapitalist and interstate competition, based on this global machinery system that tends to ubiquity, requires not only mapping the intricate and sophisticated productive and unproductive relationships and articulations that data from the global machinery system establish with capital, but also to investigate and specify the key nexuses of development and control of this system. In this sense, the next part of this paper seeks to contribute to this task and highlight some competitive axes and dynamics that emerge from a systemic reading of ICT in its own terrain, that is, as a technological and machinery system.

PART II: IMPLICATIONS FOR COMPETITIVE DYNAMICS

6. The ICT system and its nexuses

The understanding of these technologies as a key technological system underpinning distinct waves of modernization, which is constituted from the stacking of technologies that coevolve and engenders a historical process of constitution of a global machinery system is essential for the apprehension of the competitive dynamics among the technological great powers – as well as their strategies – and their main technological companies. In figure 1, it is possible to highlight two types of general dynamics in the technological development and historical evolution of this system, namely, the coexistence of processes of centralization and pulverization of machinery and productive capacity, that is, its centralization at the base and at the top and pulverization in the middle of the stack. While its base and top are extremely concentrated, both due to economic and political factors, its development presupposes and depends on diffusion and pulverization, in what we understand as waves of modernization.

The concentration is especially marked in semiconductor manufacturing equipment and the manufacturing of the most advanced semiconductors – whose productive and technological interactions constitute the fundamental nexus of the system. Such concentration derives from both economic factors – such as the large scale of capital requirement and R&D expenditures, the long maturation time of investments, the increasing returns to scale, and the very high degree of technical complexity involved in productive processes (Majerowicz, 2015; Platzer, Sargent and Sutter,2020) – and political factors, such as the technological transfer and relations with the U.S. defense sector and the fierce protection of industrial and technical secrets (Goodwin,1998; Sandia, 2001; Atta and Slusarczuk, 2012; Williams, 2019). Illustratively, for the productive processes in the manufacturing of the most sophisticated chips today, only one company in the world – the Dutch ASML, which has historical technological ties with the US defense sector (Atta and Slusarczuk, 2012) – produces the Extreme Ultraviolet photolithography machine[17] capable of carrying out these processes. Only a few semiconductor

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[17] Photolithography machines largely dictate the pace of technical progress in semiconductors to date, and access to new machines is a key factor in determining superprofits in the semiconductor and electronics industry (Atta and Slusarkzuc, 2012; Majerowicz, 2019).

companies from the US, Taiwan and South Korea (e.g. TSMC, Intel, Samsung) are able to access these machines and carry out their productive use in chip manufacturing. Meanwhile, the Chinese company SMIC has had its access to the equipment denied through US pressures over the Dutch company (Flynn, 2020; Research and Markets, 2021; Alper, Sterling and Nellis, 2020).

Just like the base, the top of the system is also marked by a strong concentration of machinery and productive capacity. As previously discussed, it is the centralization of high-power computing capacity – the productive consumption of semiconductors – that acts as material support for Big Data private production and the statistical models resulting from machine learning. The storage and processing of this data requires large scales of capital for acquiring the machinery in Data Centers, as well as their substantial energy consumption and maintenance. Here, technical barriers co-constituted by technological exclusivist policies are significantly less relevant. Thus, even though the number of companies operating in the business is small, it is much higher than in the base, with companies such as Google, Amazon, Microsoft, IBM, Apple, Huawei, Alibaba, Tencent, Baidu.

In contrast, the concentration at the top is predicted and depends on the diffusion and pulverization of semiconductors and electronic devices in the economy, civil society, government, and traditional infrastructure. The more widespread the pulverized consumption of semiconductors, the greater the imperative for the concentration of machinery at the top and the greater the scope for the development of AI-based partial and full automation, expanding the branches and activities susceptible to AI's application[18].

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[18] Thus, the dynamics of concentration and pulverization of semiconductor consumption – whether productive or mixed-use – are manifested in the very structuring of the AI industry, whose production is understood in two phases, training and inference. The training of the algorithm with data masses – to obtain the statistical model that embodies the extracted patterns – occurs through the use of AI training chips, which are high-powered and consumed centrally in facilities dedicated to these purposes. Once the model is obtained, a simple software, this is then embedded in the most distinct electronic devices and objects – such as smartphones and surveillance cameras – through AI inference chips, which are low cost and low power chips, whose function is to face unknown data and classify them using the embedded statistical model. Thus, the pulverization of semiconductor consumption is both a premise and a result of AI, in as much as inference chips become the manifestation of the centralized power of data over the scattered parts of the global machinery system. This particular arrangement of computational power and its centralization-pulverization dynamics support and reflect the understanding postulated by Durand (2020) regarding Big Data: "The symbolic productions that emanate from individuals but that, when multiplied and aggregated, assume a form that becomes unrecognizable to them, this is what Big Data is: a 'sea of data' where algorithms will extract a surplus that emanates from individual actions but which, in the aggregation process, comes to transcend them and returns to them metamorphosed.

Between the social and Big Data, there is more than one analogy. Big Data is certainly not all the social but belong to the social. They come from a dialectical movement: first, the symbolic crystallization of collective power captured in statistical regularities; then feedback from this power on individuals and their behaviors."

6.1 The ICT system as a whole: No Cold War

In this context, some central elements for competition among technological great powers and large technology companies come to light. First, it becomes evident that, from the coevolution and the wide diffusion of these technologies to different areas, a system of high complexity emerges, with an enormous and growing degree of differentiation in its inputs, final goods, and applications. Therefore, it is highly unlikely if not impossible to internalize this system in its completeness inside the borders of a single country, no matter how large the country is, without sacrificing its complexity.

Illustratively, from the analysis of only one of the most recent components of this system, AI chips, Ernst (2020, p. 14) states: "That chip can only function if it is integrated into a multilayered ecosystem and if developers are willing to develop AI applications around this specific chip". As a result, the author concludes: "No country, not even the United States or China, can bring together all the different layers of that ecosystem. Hence, access is needed to highly specialized GVCs that transcend national borders." (Ernst, 2020, p.14).

If for only a specific high-tech input of this system it is already difficult for experts in the semiconductor industry to envision the viability of a complete nationalization of the supply chain, the ambitions to internalize the entire industry and, further, the whole system, seem even more detached from the limits of possibilities imposed by the materiality of the contemporary machinery system as historically constituted. Therefore, the idea that the current Sino-American dispute acquires the contours of a new Cold War is not only unreasonable from the point of view that there are no two "contending modes of production and opposed models of society" in dispute (Dyer-Witheford and Matviyenko, 2019, p. 21), but also for postulating a digital division into two compartmentalized blocs, disregarding the implications posed by the eminently global technical and productive aspects of this system.

Although the machinery system is global, the most sophisticated productive and technological part of this system’s industrial base, its fundamental nexus, is controlled by a handful of developed countries that are military allies, namely the U.S., South Korea, Taiwan, Europe, and Japan. China is not only technologically lagging behind in this fundamental nexus, but it also has very low productive capacity vis-à-vis its consumption[19] (ICinsights, 2021b),[20] and it does not even have certain productive subsectors – in this respect, like all other countries in the world. Thus, the most plausible hypothesis is that, instead of "two antagonistic blocs", if the U.S. and allies decide to tighten the pressure on China, it would constitute only a greater or lesser degree of decoupling and exclusion of the country from the global machinery system than the formation of two rival blocs.

Moreover, even if it were possible for a country to internalize this entire system, replicating it in its entirety on a national scale – as it has been expressed in Chinese ambitions and rhetoric of technological self-sufficiency in general and in semiconductors in particular (Buck and Chenne, 2021; Sutter, 2021; State Council, 2014, 2015) –, such an undertaking would reduce not only the degree of complexity of the system – compromising, for example, the variety of semiconductors dedicated to the most diverse applications – but would also impact the degree and speed of diffusion of semiconductor consumption, which would be limited by domestic productive capacity. This limitation would, in turn, bring technological obstacles, since the degree of diffusion of these technologies and the expansion of the contemporary machinery system are important for the very unfolding of the system and its technological development, especially with regards to data production and the possibility of automation.

6.2 Fundamental nexus control: the US structural power in the ICT system

Although the ICT system has its genesis in the U.S. academic-military-industrial complex (Medeiros, 2003; Noble, 2011), the process of converting these military technologies to the civil sector – which occurred especially from the 1970s and 1980s and was followed by the privatization of the Internet – and their diffusion in the first wave of modernization are simultaneous to neoliberalism, so that the very constitution of the global ICT machinery system was predicated in the globalization of production. The formation of the ICT technological system was, therefore, based not only on the global diffusion of the consumption of electronic devices and digital infrastructure, but also on the international productive fragmentation of its industrial base (e.g. electronics industry, semiconductors). The developments and coevolution

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[19] "[...] IC production in China represented 15.9% of its $143.4 billion IC market in 2020, up from 10.2% 10 years earlier in 2010. [...] Of the $22.7 billion worth of ICs manufactured in China last year, China-headquartered companies produced only $8.3 billion (36.5%), accounting for only 5.9% of the country's $143.4 billion IC market." (ICinsights, 2021b)

[20] "The localization rate of semiconductor equipment in Mainland China is merely 11.5%, and the China-made semiconductor equipment makes up roughly 2% of the global market." (Research And Markets, 2019).

of this system are also expressed in the increase in the breadth and depth of global value chains (GVC), as the GVC of personal computers was followed by the mobile communications GVC, and further succeeded by the emergence of the AI GVC, "involving a greater diversity of stakeholders on multiple GVC layers" (Ernst, 2020, p. 13). It is this historical process that makes the nature of such a system eminently global, even though its origin can be well established in the U.S. defense sector (Morris, 1990; Mazzucato, 2014; Platzer, Sargent and Sutter,2020) and such sector keeps being fundamental to ICT technical progress (Majerowicz and Medeiros, 2018; DoD, 2021) [21] .

Despite this process of globalization, globalization occurred in a controlled manner (Majerowicz and Medeiros, 2018), considering that the all-encompassing character of the contemporary machinery system – therefore, the myriad of uses to which it lends itself and the new mediations it engenders with its expansion – makes economic, political, and national security issues inseparable. Therefore, the globalized constitution of this system, and, in particular, of its industrial base, took place in a heterogeneous way, under the control of the U.S., maintaining the following general characteristics:

i) the simple and unskilled labor-intensive productive steps were off-shored to any and all parts of the globe where there were cost advantages;

ii) the most advanced manufacturing processes, on the technological frontier, of high-tech inputs had a much timider degree of globalization and tended to be subjected to regulations – which sought to keep these processes in the domestic economy –, as well as the production and export of semiconductor manufacturing equipment (GAO, 2002; Khan, 2020); [22][23][24]

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[21] "Modernizing our military requires successful research, technology maturation, prototyping, systems integration, and test capability to turn innovative and disruptive technology into fielded and sustainable military systems. The Fiscal Year 2022 President's [of the Department of Defense] Budget requests $2.3 billion for various microelectronics efforts crucial to long-term national security. " (Dod, 2021, p. 3-2).

[22] According to the Semiconductor Industry Assocaition (SIA), the U.S. semiconductor industry maintains the largest share of its manufacturing base (43%) in the U.S. compared to any single country (SIA, 2021).

[23] For example, in 2016, the Taiwanese government required TSMC, the largest foundry of the world, to initiate more sophisticated new productive processes in Taiwan before creating productive capacity with the current technological process in mainland China, which should be limited to a maximum of three plants (Clarke, 2016). Government limitations on the transfer of Taiwanese companies' cutting-edge productive capacity in semiconductor manufacturing have been in place for a significant period (Chu, 2013).

[24] In addition to domestic regulations, semiconductor manufacturing equipment are also under the scope of the Wassenaar Arrangement, a voluntary international agreement on export controls of conventional weapons and dual-use (civil-military) goods and technologies.

iii) only a few military allied countries – due to particular geopolitical circumstances – have received technical assistance and technological transfer from the U.S. to extrapolate "i" and develop "ii" (Majerowicz and Medeiros, 2018);

iv) even with the development of some of the allies in the fundamental nexus of the ICT system, the U.S. has shown a great capacity to handle them over the decades, both by the political restriction of their industries (Japan) and by the help provided in creating other economic competitors among the military allies (South Korea and Taiwan) in the industrial base to prevent losing its dominance over the fundamental nexus (Majerowicz and Medeiros, 2018).

This control over the fundamental nexus – that is, the semiconductor manufacturing equipment industry and semiconductor manufacturing, as well as the interactions between these segments of the industrial base – is what gives the U.S. structural power in the ICT system (Majerowicz, 2019). This power is revealed in its direct and indirect dominance, together with its military allies, of the semiconductor manufacturing equipment industry[25] and the semiconductor industry[26]. In the semiconductor industry, historically, the U.S. has been able to recover market share from its economic competitors in the world market stemming from changes in the signal of U.S. domestic policy (Morris, 1990; Majerowicz and Medeiros, 2018). Moreover, considering that the interactions expressed in this nexus are central to the technological development of the entire system, they become the focus of technological exclusivist practices.[27]

In this context, facing the unviability of a country to replicate the complete system in its diversity, the second-best strategy is to control the key elements of technological development and the key subsectors. Considering that this system is formed by a stack, it follows that no matter how developed the country or company is in the upper layers, without the production

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[25] The world's leading semiconductor machinery companies are from the U.S., Japan and the Netherlands (VLSI Research, 2021).

[26] According to SIA (2021), the global semiconductor market, according to companies' headquarters and excluding foundries, was divided as follows in 2020: USA (47%), South Korea (20%), Japan (10%), Europe (10%), China (5%) and other countries (8%). ICinsights (2021) offers statistics in which American dominance is even greater: USA (55%), South Korea (21%), Taiwan (7%), Europe (6%), Japan (6%) and China (5%). Both data sources show a growth in the U.S. market share between 2018 and 2020, while China's remained stable.

[27] The tacit or uncoded knowledge, in the terms of academic literature on innovation, or industrial secrets, long discussed by classical political economists, are evident in this sensitive industry, given the sophistication of the equipment and production processes in question (Majerowicz, 2019): "part of this is due to the fact that both foundries and equipment vendors work together to fine tune how to extract maximum yield out of the production lines. This co-developed knowledge is often locked under NDA [non-disclosure agreements]" (Williams 2019).

and/or access to the goods of the lower layers, this development is halted.[28] This is one of the main aspects that gives the U.S. structural power in the ICT system stemming from the control of the fundamental nexus. It is not, however, just a matter of controlling supplies essential to digitalization, because the structural power also emanates from the fact that the set of technological possibilities in the upper layers are given by their industrial base – so that the pace of technical progress on that base has the ability to propagate throughout the system.[29]

It is precisely through the leverage of this structural power derived from control over the industrial base of digitalization – whether it is established directly over American producers and companies, or indirectly over the economies and producers of military allied countries – that the U.S. has been seeking to contain China's ICT ambitions and the effective Chinese success in the upper layers of this system (Majerowicz, 2019; NSCAI, 2021). However, China joined the world market during the neoliberal period and began to play a central role in the global constitution of the ICT system, both from the point of view of final consumption – since it has become the fastest expanding market in recent decades and the main market for a myriad of electronic goods in units sold (BBC, 2011; Agence France Press, 2011) – and the point of view of internationally fragmented production – becoming the world's leading electronic producing center and, therefore, the main consumer of semiconductors on the planet since 2005 (ICinsights, 2020). This important role imposes self-limitations to the US full leverage of its structural power in the ICT system, given the various circuits of capital accumulation of US technology companies that have in China their main market for realization.

While the leverage of the US structural power can place serious obstacles to Chinese development in ICT, the U.S. cannot use this strategy very effectively without hampering itself. Thus, competition tends to intensify in the quest to move forward the technological frontier with a long-term horizon – as signaled at the end of the Obama administration (PCAST, 2017) and affirmed in the Biden administration, especially with the proposed Innovation and

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[28] This diagnosis is also reflected in the Final Report of the U.S. National Security Commission on Artificial Intelligence (NSCAI, 2021), in which semiconductor manufacturing equipment are identified as a critical bottleneck for Chinese development in AI. Thus, the report recommends: "Utilize targeted export controls on key semiconductor manufacturing equipment (SME). Where possible, the United States should use export controls to prevent competitors from obtaining AI capabilities that would grant them strategic or military advantages. The primary U.S. export control target to constrain competitors' AI capabilities should be sophisticated SME necessary to manufacture high-end chips" (NSCAI, 2021, p. 230).

[29] The U.S. Department of Defense (2021) is explicit about the impacts of advances in semiconductors on technological development at the top of the stack when requesting a budget for research and investments in microchips. According to the DoD (2021, p. 3-2), "Advanced capability microelectronics technology development directly influences success in fielding disruptive technologies, including the following Advanced Capability Enablers", namely hypersonic, AI, and 5G.

Competition Act, whose budget of $250 billion provides $52 billion for semiconductors (BIDEN, 2020; NSCAI, 2021; The White House, 2021; Franck, 2021) –, rather than a mere war of short-term positions based on prohibitions to halt China's productive capacity and generate technological obsolescence. In this sense, if the U.S. can move faster on the technological frontier, China's technological obsolescence is a corollary and occurs without the need to short-circuit capital accumulation in many of the country's large and important technology companies. On the long-term horizon, if there is no technological disruption that supplants the "silicon machinery system", the U.S. also get ahead in the race due to its structural power stemming from the control over the fundamental nexus, with all the implications this has to the pace of technical progress.

Meanwhile, in the medium term, the U.S. seeks to strengthen its dominance over this nexus of the industrial base of digitalization, both for security and economic reasons, pursuing the implementation of policies that increase domestic manufacturing capacity for "supply chains for critical sectors and subsectors of the information and communications technology (ICT) industrial base" (The White House, 2021b). This concern stems mainly from the fact that much of the global manufacturing capacity in sophisticated chips is no longer in the U.S. – whose share felt from 37% in 1990 to 12% in 2020 (SIA, 2021; The White House, 2021a) – and is now concentrated on the territory of its military allies, South Korea and Taiwan, worrying the US establishment due to the geographical proximity of such industrial base to China (Moore, 2021).

6.3 The race for the downstream nexus: Big Tech, from consumption to semiconductor production

It is undeniable that there is, contemporary, a sharp competition among the Big Tech for the collection and capture of data, as Durand (2020) stresses. However, in his analysis and in several other authors, this competitive dynamic tends to be separated from the analysis of the ICT technological and machinery systems as a whole, focusing only in the most visible surface of the stack, with more direct implications in everyday life. In Figure 1, this dynamic can be seen simply as just the dispute for data aggregation, that is, the centralization at the top of the technological and machinery system.

An important contribution to the analysis of intercapitalist competitive dynamics can be found in Srnicek (2016), who examines the different models of digital platforms. Beyond postulating the tendency towards monopolization engendered by network effects and highlighting the digital "enclosures" of platforms – which are key aspects in Durand's (2020) technofeudalism –, Srnicek (2016) advances two competitive dynamics that consider the broader ICT system. Even if predicated as extensions of the imperative of collecting more data, these dynamics are: i) the imperative of platforms to develop the full stack, that is, "a tendency to increasingly take on all the features of the stack, from hardware to software"[30] (Srnicek, 2016); (ii) and, considering the stack, the tendency of large platforms to pursue key and strategic positions, in a rhizomatic integration, in which "the strategic importance of a position has much more to do with controlling data from businesses and customers than with just being lower in the stack" (Srnicek, 2016). In relation to the first trend, he highlights both the centrality of the "extension of sensors" – particularly stressing the electronic consumer devices of the Internet of Things, in which sensors are embedded in homes and the most trivial consumer goods – and the "means of analysis", emphasizing the role of advances in computer servers and hardware and investments in AI.

If it is a fact that the production of raw data and its subsequent transformation into Big Data and, also, in statistical models derived from its compression via AI require both the embedded diffusion of semiconductors and their technological development – since more powerful servers come from more powerful chips –, the relationships of individual capitals with these machines are distinct and bear consequences for competition. The process of diffusion of semiconductors in general and the Internet of Things in particular takes place extra-frontier of the technology firm. That is, the ownership of these machines does not tend to accrue to the companies, which sell them – i.e., they are not their fixed assets –[31], even if the permanent integration of these machines in the contemporary machinery system engenders the creation of constant channels for the absorption of the data produced by the use and/or automatic operation of such devices and for the application of AI in these same devices.

This dissemination, in general, takes place in the form of tie-in sales – electronic devices and embedded software –, therefore constituting differentiated sources of profit for the company(s) involved, or in the sale of electronic devices with free embedded software, whose counterpart may be access to data, as Srnicek (2016) stresses. This process of embedded diffusion of semiconductors, therefore, does not occur, in general, as a mere counterpart to the

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[30] Srnicek's (2016) stack is not exactly the same as we are dealing with, because here we also include the industrial base of digitization as a whole – the silicon machinery system – which tends to be partially left out in the analyses of the ICT stack.

[31] differently, Srnicek (2016) confuses, to a certain extent, the nature of the relationships between these capitals and the ICT machinery system as a whole, when treating personal consumption sensors as if they were fixed assets of technology companies: "the fact that information platforms require the extension of sensors means that this is a trend contrarrestante to the platform Lean".

data and, for total capital, as will be seen in the next section, it is much more conditioned to national strategies than those of individual capitals. That is, the ICT machinery system as ubiquitous machinery, which denies the factory as a *locus par excellence* of the machinery system, finds central determinations in state policies – which drive technical progress in semiconductors and the development and implementation of digital infrastructure –, state industrial strategies and capital accumulation patterns.

In contrast, the machinery held by Big Tech in the form of concentrated and centralized computing power, the "means of analysis", is in fact fixed capital of these companies. Here, the productive consumption of semiconductors is key to the quality and the expansion of Big Tech services and competition between individual capitals in this sphere of accumulation. Moreover, it has been widely recognized in the academia and the industry that both the emergence of large masses of data and technical progress in semiconductors (computing capacity) were the enabling elements for the emergence of the AI industry, and that both continue to be central to competition in this industry (Lee, 2018; Ding, 2018; Ernst, 2020). There is also, therefore, a race for computing capacity that is not limited to data access.[32]

It is this centrality of technical progress in semiconductors for the technological development of the upper layers of stack that explains the Big Tech's recent movement of descent from the mere consumption to semiconductor production, albeit in general only at the semiconductor design stage. Thus, large U.S. and Chinese technology companies began to seek to develop their own designs of AI and/or cloud computing chips. This is the case of Google, Apple, Amazon, Microsoft, Baidu, Alibaba, Tencent, ByteDance – the owner of TikTok – and possibly even Facebook (Fitch, 2020; Global Times, 2021). And this move towards the industrial base of digitalization is strategic for competition between large technology companies, but not because it is "rhizomatic" and associated with the control of third-party data. It is about the competitiveness gains associated with the internalization of one of the key nexuses of technological development in the ICT system, namely, the downstream nexus in Figure 1, in which interactions occur between semiconductor consumers and semiconductor producers through customer's specifications of the parameters that should drive chip design. By internalizing this relationship, this interaction occurs in a much more refined way, resulting

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[32] According to Ding (2018, p.4), technological development in AI has four central parameters, namely "(1) hardware in the form of chips for training and executing AI algorithms, (2) data as an input for AI algorithms, (3) research and algorithm development, and (4) the commercial AI ecosystem."

in chip designs much more suitable for the computing needs of each firm and their applications.[33]

Such as for countries, it is impossible for companies to internalize the entire ICT machinery system. This impossibility makes them seek to build strategic partnerships with firms in the adjacent layer – as in the case of the special relationships established between certain semiconductor manufacturing companies and the producers of photolithography machines, in the fundamental nexus, to obtain priority of access to the newest machines (Atta and Slusarczuk, 2012) – or, when feasible, to internalize the very nexus of key technological interactions – expressed in this movement of internalization of semiconductor design by the large technology firms that consume them. The latter movement applies not only to the case of cloud companies, but also to the case of producers of electronic devices, such as Huawei, whose chip design subsidiary, HiSilicon, has been credited by much of the success of Huawei's products (Triggs, 2018).

Thus, the aspect of the ICT machinery system that affirms the factory is also felt in intercapitalist competition even for those companies that have been associated only with business models of value predation and not production by parcel of the academic literature – such as cloud companies and even advertising-focused companies such as Facebook. As a machinery system that extrapolates the factory, the ICT system, in order to develop technologically, must always return and refer to the shop floor, must synchronize and tune with it for the continuity of technical progress and its propagation from this industrial base.

7. The waves of modernization and the acceleration of diffusion

As previously discussed, technical progress in semiconductors and semiconductor manufacturing equipment not only enabled the computing capacity needed for the development of AI or Big Data Analytics, but also the very emergence of Big Data. It was the cheapening, the increase of power, and the miniaturization of semiconductors that enabled the mass diffusion of semiconductors in both goods whose computing and communication capacity are

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[33] In addition to the demand for higher performance, Fitch (2020) also highlights the search for minor costs implied in this movement: "Amazon, Google and Microsoft each are estimated to operate millions of servers in globe spanning networks of data centers for their own use and to rent out to their millions of cloud-computing customers. Even small improvements in performance and minute reductions in the cost of powering and cooling chips become worth the effort when spread across those vast technology empires."

primary functions and in those in which they are secondary functions, referring here to the first and second waves of modernization based on ICT respectively.

Despite this same determination to both waves of modernization – and, consequently, the role of the state in them can be already perceived, particularly that of the U.S., for the advancement of the technological frontier in these crucial sectors of the "silicon machinery system" –, it can be said that the propagation dynamics of these modernization waves keep important determinations that differentiate them. This is particularly valid when considering the role of the state in them and interstate competition, since the project of "digital intermediation of everything", or the ubiquity of the modern global machinery system, entails state action and coordination that go far beyond corporate strategies and workers’ decisions regarding consumption.

It is true that the state was also fundamental to the first wave – just think of its role in the emergence of the Internet and in the implementation/regulation of telecommunications infrastructure, as well as in the computerization of public companies and services or in encouraging the adoption of computers and computerized industrial control systems by private companies. But the first wave really gained momentum due to the explosion of personal consumption of these goods. If initially the first wave, on the one hand, moved due to the cheapening of personal computers and smartphones, on the other, it found limitations in the income level of working families. However, as smartphones became indispensable for the insertion in the labor market, including in the informal sector, and for access to public services (Morozov, 2018), they were incorporated into the subsistence wage of workers, even in much of the capitalist periphery. This process did not occur with the other mixed-use goods of the first wave, such as personal computers and tablets. In this sense, the hypothesis presented here is that a significant portion of the global demand that sustained the boom of the first wave of modernization largely decoupled from the income level of workers, possibly shifting the level of consumption of other subsistence goods, which would provide support to personal demand for smartphones even in the face of stagnation or decline in workers' incomes.

In contrast, it is not to be expected or there is nothing to ensure that the advertised personal consumer goods of the second wave – e.g. smart surveillance cameras, smart toasters, TVs and appliances[34], voice assistants, smartwatches – will be integrated in the subsistence

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[34] Certainly, it is possible that in the long run the traditional versions (without sensors and chips) of these goods would progressively stop being produced or become a minority portion of industrial production, so that, through the wear and tear and the need for the eventual replacement of workers' consumer goods, these versions with information and communication capabilities become part of the workers' basket of subsistence goods.

wage. In a historical period of fierce global competition between workers and informalization of domestic labor markets – made possible by ICT themselves –, with a vast industrial reserve army (Foster, McChesney and Jonna,2011; Huws, 2014, 2019; Jonna and Foster, 2016; Fontes, 2017), the pressure of these factors on workers' wages does not seem to make wages a promising source of demand for the support of the second wave of modernization. And as far as we know, Big Tech is not providing this entire range of products – for the "extension of their sensors" – free of charge in exchange for data, as data is far from the only relevant source of profitability associated with the modern global machinery system. Thus, in addition to the determinants that involve state action for the formation and propagation of the first wave, the second wave seems to require an even more prominent role of the state, especially when we consider that the state should assume the role of a central demander for the products of this wave, since personal demand tends to be much more restricted compared to the previous wave.

Moreover, the project of "digital intermediation of everything" has only one of its relevant components in the goods used for personal consumption. Three other components are worth highlighting associated with this project. First, the transformation of traditional and urban infrastructure (e.g. smart grids, smart cities), in addition to the very renewal of the mobile telecommunication system with 5G, which introduce new intermediations in the most distinct areas of social life. Secondly, the transformations in the productive structure stemming from the diffusion of the most recent developments of the ICT technological system. These refer not only to the manufacturing industry – a component of the "digital intermediation of everything" translated into the projects of "Industry 4.0" –, but also on services and, especially, agriculture, which has remained, so far, the sector relatively less touched by the diffusion of semiconductors in productive processes. Finally, the transformations in the state apparatus itself, including public services, with emphasis on two processes, namely: *(i)* the technological upgrade and the development of state repressive apparatuses, including ubiquitous surveillance, which is also implemented through the first component, with smart cities and intelligent transport systems (Graham, 2016); and *ii*) the reconfiguration of the state itself in relation to capital, with privatization within the public machine, which will depend on Big Tech to be operational, both for providing public services as education and for the most common activities (Morov, 2018).

Thus, the state is a direct executor (e.g. smart cities, transport infrastructure), activator and coordinator, through industrial policies, and the object of the second wave of modernization based on ICT. These instances of state action highlight what Medeiros (2018) provides due centrality, namely, the role of government procurement for technological development and dissemination. Analyzing China’s economic development, Medeiros (2018, 2013) diagnoses that infrastructure investments were the engine of the country's growth, while government procurement and demand for innovation have propelled its technological development. As previously discussed, the technological development of the ICT system has in the degree of diffusion one of its important determinants, thus placing another sphere in which the state appears as fundamental to contemporary technological development.

Therefore, it is mainly around the states of the great technological powers that the second wave of modernization has gained momentum and not around the corporate strategies of Big Tech, even though these are the major suppliers and beneficiaries of the projects of "digital intermediation of everything" headed by these states. As diffusion affects technological development and enables the emergence of new branches of accumulation and the reconfiguration of different markets stemming from the new mediations made possible by ICT, which makes room for Big Tech to enter established sectors challenging incumbents – but also to privatize public services, urban spaces and part of the state's operational structure –, a race is established for the implementation and dissemination among the technological great powers in close alliance with their technology companies, tending to provoke the acceleration of the second wave. This is particularly true for the cases of China and the US.

7.1 The Sino-American dispute and the race for implementation

In China, in addition to the plan for the manufacturing industry in general, Made in China 2025 (State Council, 2015), the long-term ambitions put forward by vision 2035 (Central Committee, 2020; Wong, 2020) and sectoral policies – with emphasis on the 2014 National Guidelines for the Promotion and Development of the Integrated Circuit Industry (State Council,2014), the 2017 New Generation Artificial Intelligence Development Plan (State Council,2017), and the 2020 Policies for Promoting the High-Quality Development of the Integrated Circuit Industry and the Software Industry (State Council, 2020; Zhang, 2020) –, the Chinese Communist Party (CCP) has launched several policies aimed at the dissemination of ICT on the different aspects of the economy, society, and national security. After controlling what could have become a serious health crisis, in March 2020, China saw as a way out for its economy a package of public-private investments, with a large participation of domestic Big Tech, in what it has been calling the "new infrastructures", namely: 5G infrastructure, AI, Big Data, Data Centers, Industrial Internet, ultra-high voltage power transmission lines, batteries for charging electric vehicles and high-speed long-distance transportation (Liu, Li and Ting-

Fang, 2020).[35] From the point of view of ICT, this perspective reveals a strategy for disseminating these technologies as a technological package, a set whose implementation should go *pari passu* and in which the implementation of each technology tends to strengthen and propel the dissemination of the others.

It should be noted, however, that the role of government procurement in the development of the ICT system in China goes far beyond such an investment package. The case of the development of the AI industry in the country is emblematic. In 2019, the AI software and application market in China totaled US$ 2.89 billion[36], approximately 51% of which related to computer vision technology (IDC, 2020; Shiyue, 2020). The main vector of demand in computer vision was government spending on public safety and smart cities (IDC, 2020; Shiyue, 2020). The highlight in this technology is facial recognition– one of the applications in which China leads worldwide, followed by the U.S. (Financial Times, 2021; Ding, 2018) –, whose demand in China was basically destined to public security (72% in 2015), followed by far by finance (20% in 2015) (chyxx.com, 2020). Thus, in addition to the start-up unicorns in AI (Megvii, Yutu, Sensetime, Cloudwalk), the big companies in the security industry are rapidly gaining market shares of the computer vision market in China, particularly the state-owned Hikivision and the mixed capital company Dahua (IDC, 2020)

Here, it becomes clear how the Chinese advantage in the technological diffusion of AI, stemming from government procurement, contributed to the conversion of the country to the position of primacy in facial recognition. According to official statistics, in the 2010s, government public security spending in China exceeded spending for national defense, so that, in 2019, it was 22% higher (NBS, 2020). In this sense, in addition to the importance of China's military modernization strategy for its technological development and the civil-military nature of ICT (Trebat and Medeiros, 2014; Majerowicz and Medeiros, 2018), social control is consolidated as one of the main objectives of the state's action in pursuing the project of "digital intermediation of everything".

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[35] This investment package seeks to achieve short- and long-term objectives, acting macroeconomically to maintain the growth rate and ensuring the infrastructures considered as a precondition for the deepening of digitalization, “networkization”, and "intelligentization". The centrality of the CCP’s leitmotiv "digitalize, networkize, and intelligentize" (Xinhua, 2018; People's Daily, 2019; Xu, 2019) is such that it gained expression in the methodology of GDP measurement, with the National Bureau of Statistics producing metrics on the “new economy” and the “three new” sectors, accounting for digitalized and internet-connected activities in agriculture, manufacturing, and services as portions of GDP (NBS, 2020a).

[36] Including hardware, this market reached $6 billion (IDC, 2020).

The U.S. stance in the technology dispute during the Trump administration had a short-term logic, with the series of bans on Chinese companies (e.g. Huawei, Hikivision, Dahua, Megvii, Yutu, Sense Time) and the interference and pressure on the relations of U.S. allies and their companies with Chinese companies (BIS, 2019, 2019a; Alper, Sterling and Nellis, 2020). Trump mobilized the escalation of tension in the technological dispute with China for electoral purposes, but his policies reverberated deep concerns of the US establishment. At the end of the Obama administration, several documents were published stressing the need for government resource targeting and support, with industrial policy, in the ICT sector, particularly in the call for strengthening the semiconductor industry and the outline of a national plan for AI (PCAST, 2017; The White House, 2016; NSTC, 2016). In addition to emphasizing the need to ensure U.S. supremacy in semiconductors, the President's Council of Advisers on Science and Technology (PCAST, 2017) warned about Chinese industrial policies. These had been achieving great results in ICT, in a context in which the ambitions and determination of the party-state showed no signs of cooling down if left by themselves.

The Trump administration represented a solution of continuity to this response that had been outlined by Obama. The Republican's long-term response to this competition was piecemeal, delayed, and disjointed. Several analysts also highlight that China's 2017 national plan for AI would have been, in practice, the implementation of the Obama plan (Allen and Kania, 2017; Metz, 2018). It was late in 2019 when Trump served the industry’s calls and presented a national plan for AI (The White House,2019). However, the piecemeal and disjointed nature of this initiative should be emphasized. Still in the final days of the administration, Trump implemented a new round of restrictions on Chinese companies and applications (e.g. Xiaomi, Alipay, WeChat Pay, QQ wallet) (The White House, 2021c).

These short-term responses bequeathed to the Biden administration, however, were somewhat welcome, as they put the president in a position of power to leverage in his negotiations. However, the key component of Biden's response is systematic, long-term, and structural, deepening the technological race. With the abbreviated name "Made in America" (Biden, 2020), referring directly to the Chinese industrial policy, Biden's administration plan foresees a comprehensive industrial and innovation policy based on infrastructure investments ($400 billion), government procurement based on local content criteria – signaling for a shift in posture in trade negotiations – and vast R&D investments ($300 billion), especially in disruptive technologies. Sectorally, the focus will be not only on telecommunications (5G) and AI, but also on clean energy and clean vehicles and the relocation of critical production chains (e.g. semiconductors, pharmaceuticals) [37] (Biden, 2020; Federal Register, 2021a, 2021b). This strategy seeks to rearticulate relations with allied countries to provide a coordinated response to China, while the U.S. export insertion is seen as residual to the industrial capacity constituted to serve the domestic market, as in China.

There is, therefore, a growing convergence between Chinese and US policies and practices: China mimics the U.S. civil-military national system of innovation, adapted to its specificities (Trebat and Medeiros, 2014), and the US affirms in its strategy many of the key instruments that have underpinned the Chinese development in recent decades, such as infrastructure investments and government procurement. This tendency to convergence of Chinese and US state action – both from the point of view of the innovation system and the instruments of economic action – is another central element that differentiates the current Sino-American competition from that existing during the Cold War.

Roughly speaking, it can be said that the Cold War was marked by two fundamental encapsulations that dictated both the paths of the dispute between the US and the USSR and its ultimate result, namely: the economic encapsulation of the USSR in relation to the global capitalist economy and the encapsulation of the Soviet innovation system in the military sector relative to the civilian sector. The latter encapsulation implied the absence or the very low degree of propagation of technical progress developed in the military sector to the updating of civilian productive capacity, as opposed to the American innovation system. In contrast, the contemporary Sino-American dispute is marked by economic intertwining and the convergence of the national innovation systems, in particular, and state action, in more general terms, reflecting characteristics of contemporary intercapitalist competition and imposing distinct dynamics on the technological and economic race vis-à-vis the Cold War.

Thus, the ongoing transformations point to the deepening of the technological competition between the U.S. and China, with the significant U.S. repositioning, based on the understanding that the inevitable path to maintain its technological supremacy is the leap forward, pushing the technological frontier. This exit forward, however, is also a race for militarization (Medeiros, 2003; Majerowicz and Medeiros, 2018) – including the domestic spheres, in what Graham (2016) called a new urban militarism – and the deepening of public-private digital surveillance (Greenwald, 2014; Majerowicz, 2020). Moreover, it is a fierce dispute over the markets and infrastructures of other countries, especially those peripherals,

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[37] In addition, the dispute will also intensify in traditional sectors in which Chinese state-owned enterprises stand out, with an emphasis on heavy industry, especially steel, cement, and concrete.

whose insertion is in the condition of technological consumers – which in general tends to increase their technological distances from the center and to provide global propulsion to the second wave of ICT-based modernization.

Before the pandemic, large US and Chinese companies were already exporting technological packages and competing in third markets, in a process largely driven and made possible by their states. In January 2020, on the eve of the pandemic's arrival in the U.S., the U.S.-China Economic and Security Review Commission of the U.S. Congress addressed a report on China's development in smart cities to instruct closing measures of the U.S. market and competition in third markets (Atha et al, 2020). Under the brand of smart cities, these large technological and digital infrastructure packages, which include sensors, surveillance cameras, telecommunications, software systems, chips, and AI have become an important expansion vector for Big Tech and unicorn startups, as well as the security industry, where automation and digitalization are at full steam. The ramifications and consequences of this process in deepening the dependency of the countries receiving these packages, highly integrated with critical government and civilian infrastructure, when not military, are still incalculable.

Additionally, the crisis in capital accumulation that took off with the coronavirus pandemic – the product of ecological imbalances engendered by capitalism (Wallace et al, 2020; Wallace, 2016) – tended to intensify competition between large capitals supported by their national states, as the possible valorization spaces were sharply reduced. In this context, the digital sphere and all the infrastructure that sustains and automates it tends to have its role strengthened and accumulate even more tensions. The pandemic has been acting as a catalyst for the second wave of ICT-based modernization, paving the way for the explosive growth of online activities, through the migration and digitalization of various services and the production of digital content, accelerating the development of algorithmic automation and the subsumption of intellectual labor to capital. It has also concurred for the sudden opening of several and vast national markets, including public health and education services. Through governmental purchases of Big Tech packages, these services are disfigured in telehealth and tele-education, being privatized from within, precarized, and cheapened, while isolating and surveilling service users and health and education professionals. It is a win-win situation for the states and capitals well-placed in the "digital economy". Thus, in addition to telecommunication infrastructure, public security, and urban space management, health and, especially, education became major markets in intercapitalist competition between the U.S. and China mediated by the development of ICT, in a scenario in which different factors accumulate for the intensification of the technological dispute.

8. Final considerations

Headed by the great technological powers and their large technology companies, ICT diffusion has led to multiple and significant transformations on a global scale in recent decades, which are expressed in major analytical and theoretical challenges. In this context, numerous exuberant theses have emerged, many of them reediting and conceptually reformulating the past, either based on pre-capitalist modes of production or in previous configurations of the interstate system.

This paper initially sought to take a step back and analyze the productive structure and technological dynamics that underpin these transformations. Aiming to overcome a fragmentary analysis based on a particular technology, on the one hand, we explored the three key technologies and their interrelations in order to apprehend ICT as a technological system. On the other hand, ICTs production – both as the industrial base of digitalization and as digital infrastructure – was considered in light of differentiated diffusion processes, in two waves of modernization, involving different types of users, which were responsible for the incorporation of such technological system into a global machinery system.

As a technological system, ICT has been characterized as a coevolutionary stack of technologies, in which the base layers occupy a unique role since they constitute the technological presuppositions for the rest of the system, conditioning the technological possibilities of the upper layers and propagating technical progress throughout the system. Moreover, when considering the dynamics between production and consumption in an interactive way, the role of diffusion in technological development was evidenced and the main productive and technological relationships of this system were identified – namely, the fundamental nexus between semiconductor manufacturing equipment and semiconductor manufacturing, and the downstream nexus between semiconductor design and semiconductor consumers.

This systemic prism highlighted the physical and productive aspects of data and AI, grounding them in the manufacturing industry, that is, in the machinery system as traditionally conceptualized, in the form of the "silicon machinery system". If the role of the “silicon machinery system” for the development and dissemination of ICT is crucial, affirming the centrality of the factory system for the supposed post-industrial world, ICT also denies the factory as locus par excellence of the machinery system. ICT has been constituted as a "global electronic monster" both due to the historical process of its affirmation as enabler and substrate of globalization, and as the project of "digital intermediation of everything" headed by the technological powers together with their large technology companies.

This universalizing dynamic of the machinery system beyond the factory, which bears with it automation processes and partial automation, is also the process of universalization of the despotic system of manufacturing management, which enables the individualized control of dispersed workers, converting unproductive into productive labor. Moreover, this ubiquity associated with the global machinery system implies that its use accounts for a myriad of productive and unproductive objectives. Therefore, understanding the role of data and how this machinery system is inserted in capital accumulation entails specifying and mapping the different circuits of capital accumulation and their positioning in this global machinery structure, rejecting formulas that point exclusively to its productive (prosumer) or “predative” aspects.

Once the general conceptual aspects of ICT as a technological and machinery system were outlined, we inquired how ICT, read in their own productive and technological terrain and in their historical developmental process, impose material constraints on the disputes of the great powers and large capitals in the technology sector. Marked by the coexistence of processes of centralization and pulverization of machinery and productive capacity, these competitive dynamics were considered from four dimensions extracted from the conceptual discussion, namely, from the global technical-productive character of ICT as a machinery system, the fundamental nexus, the downstream nexus, and the technological diffusion embodied in the second wave of modernization.

The global technical-productive character of ICT as a machinery system emerges not only from the global diffusion of electronic devices’ consumption and digital infrastructure, but also from the international productive fragmentation of its industrial base, simultaneous to neoliberalism, even though this process has been heterogeneous. The result of this historical development is the constitution of a system of high complexity and with a huge and growing degree of differentiation in its inputs, final goods, and applications. Consequently, efforts to internalize or achieve self-sufficiency in this system are highly unlikely to be successful, when not impossible without sacrificing its complexity and delaying diffusion speed and technological development.

The postulation, therefore, of a digital division into two compartmentalized blocs, disregards, on the one hand, the implications posed by the global technical-productive aspect of this system. On the other hand, the idea of a new Cold War ignores that the most sophisticated productive and technological part of the industrial base of this system, its fundamental nexus, is controlled by the US and military allies, so that, instead of "two antagonistic blocs", if the US and allies decide to tighten the pressure on China, it would constitute only a greater or lesser decoupling and exclusion of the country from the global machinery system than properly the formation of two rival blocs.

In face of the unviability for a country to replicate the complete system in its diversity, the second-best strategy is to control the key elements of technological development and key subsectors. Considering the stack, we concluded that no matter how developed the country or company is in the upper layers, without the production of and/or access to the goods from the lower layers, this development is derailed. This is one of the main aspects that give the U.S. structural power in the ICT system from the direct and indirect control of the fundamental nexus. The structural power also emanates from the fact that the set of technological possibilities in the upper layers are given by the industrial base.

It is precisely through the leverage of this structural power stemming from the control over the industrial base of digitalization that the U.S. has been seeking to contain China's ICT ambitions and the effective Chinese success in the upper layers. However, the fact that China joined the world market during the neoliberal period and assumed a central role in the global constitution of the ICT system imposes self-limitations to the full leverage of the US structural power, given the various US technology companies whose circuits of capital accumulation have China as their main market. While the leverage of this structural power can put serious obstacles to China, the U.S. cannot use this strategy very effectively without hampering itself. Hence, competition tends to increase in the search for moving forward the technological frontier, with a long-term horizon, while the U.S. seeks to strengthen its dominance over the fundamental nexus, implementing policies that increase domestic manufacturing capacity.

In contrast, in the downstream nexus, competition between Chinese and US companies is much tighter. Here there is also the centralization of machinery and productive capacity – necessary for transforming pulverized raw data into private production of Big Data and AI-generated statistical models. As productive consumers of semiconductors and owners of machinery in the form of concentrated computing power, American and Chinese Big Tech compete not only for access/monopoly of data sources, but also for computing capacity, which is expressed in the recent movement of Big Tech from the mere consumption to production of semiconductors, even if in the design stage. Such a movement is strategic because of the competitiveness gains associated with the internalization of one of the key nexuses of technological development in the ICT system. Thus, the aspect of the ICT machinery system that affirms the factory is also felt in intercapitalist competition, even for those companies that have been associated only with models of value predation and not production. As a machinery system that extrapolates the factory, the ICT system, to develop technologically, must always return and refer to the shop floor.

Finally, we considered the race for technological diffusion embodied in the second wave of modernization, given the role of machinery pulverization in the middle of the stack for the technological development of the system. In this dimension of the ICT system as a machinery system that goes beyond the factory, the role of the state and interstate competition are central, since the project of "digital intermediation of everything" entail a state action and coordination that go far beyond companies’ strategies and workers’ consumption decisions. Unlike the first wave, which had in the subsistence wage a central component of demand, the support for the second wave does not seem to find in wages a promising source of demand. In addition to the determinants that involve state action for the formation of the first wave, the second seems to require an even more prominent role of the state. The state must assert itself as a central buyer, direct executor, activator and coordinator, through industrial policies, and the object of the second wave – which implies the reconfiguration of the state in relation to capital and the strengthening of state repressive apparatuses, including ubiquitous surveillance. Therefore, it is mainly around the states of the great technological powers that the second wave has been gaining momentum.

In this context, the analysis of the Sino-American race for diffusion revealed a tendency towards the convergence of Chinese and US state action, both from the point of view of the national innovation system and the instruments of economic action. This trend, added to the Sino-American economic intertwining, presents itself as another central element that differentiates the Sino-American competition from that existing during the Cold War, which was based on two encapsulations vis-à-vis the USSR. This differentiation reflects characteristics of contemporary intercapitalist competition and imposes distinct dynamics on the technological and economic race in relation to the Cold War.

Thus, the ongoing transformations point to the deepening of technological competition between the U.S. and China, with the American repositioning. This, however, is also a race for militarization – including the domestic spheres –, the deepening of public-private digital surveillance, and the conquest of foreign markets and infrastructures, especially in the periphery, with serious implications for the autonomy and sovereignty of countries receiving these technological packages.

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