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Short communication

Reconfiguring global value chains in a post-Brexit world: A technological interpretation☆

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ABSTRACT

With the uncertainties that it may entail in terms of possible trade barriers between the UK and the EU, increased exchange rate risk, restrictions on the establishment of professionals and possible changes in regulations on the environment, tax and protection of competition, Brexit could exacerbate the process of re-localisation of operations that commenced to a small extent some years ago. This process was based on technological innovations under the heading of Industry 4.0, and more recently strengthened by the supply problems that came to light during the handling of the Covid-19 pandemic. Although the social, political and institutional context matters a lot, we believe that technology is going to be a conditioning element in the ability of businesses to reconfigure the value chains in which they are involved. We propose a typology based on this technological perspective that could have considerable potential impact in defining business strategies in numerous industries and in orienting industrial policy in countries striving to acquire a more central role or to prevent themselves from being cut out of the global value chain.

1. Introduction

The value chain covers the full range of activities by firms and workers to bring a product or service from its conception to its end use and beyond [1]. This means managing a network of interconnected businesses involved in the ultimate provision of product and service packages required by end customers [2]. The globalisation of value chains has led to a segmentation in production processes which maximises efficiency in the manufacturing of products and in processes by efficiently locating the operations involved. Global value chains are normally divided among multiple firms and geographic areas. The competitiveness of companies is conditioned by the extent to which they are integrated. The requirement of being competitive limits their room for manoeuvre as regards the degree to which value chains can be externalised (including the locations to which they can be externalised, where cost is a determining factor).

Competitiveness seemed to make the globalisation of value chains a must. It also seems to have helped improve the distribution of production and income at global level, with knock-on effects in terms of welfare for many countries that would otherwise have been unable to undertake production work.

However, Brexit may boost changes in the current make up of the value chain as an additional factor to those already in place:

- The technological innovations grouped under the "Industry 4.0" concept, the increasing servitisation of industry, the gradual rise in Chinese industrial wages and trade wars have led many firms present in China to rethink their localisation strategies and decide to move back to Europe and the USA or relocate to other developing countries with more transparent institutional frameworks and less bargaining power and capacity to bring pressure to bear. As Thoben et al. [3] state, Industry 4.0 (also called *smart manufacturing* in the United States) "is based on the assumption that industrial production in the near future will be characterized by the strong individualization of products under the conditions of highly flexible (large series) production, the extensive integration of customers and business partners in business and value-added processes, and the linking of production and high-quality services that leads to so-called hybrid products." [3]; p.5). These technological advances include progress in robotisation and automation, the Internet of Things, additive

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manufacturing, cloud computing, digitisation, big data, cybersecurity, etc.

- The Covid-19 pandemic has highlighted shortfalls in personal protective equipment and diagnostic testing in numerous countries, developed and developing alike, as a result of the delocation of their textile and pharmaceutical industries to countries such as China and Turkey. It has also led to interruptions in supplies for production operations where value chains have become fragmented and internationalised.

The need to tackle these problems could boost the relocation process that began to a small extent some years ago.

Beyond the negative trade consequences of Brexit are expected to be substantial, especially for the UK and also for the EU [4], with the uncertainties that it may entail in terms of possible trade barriers between the UK and the EU, increased exchange rate risk, restrictions on the establishment of professionals and possible changes in regulations on the environment, tax and protection of competition, Brexit could exacerbate the process of re-localisation of operations that commenced to a small extent some years ago and was also affected by problems that came to light during the handling of the Covid-19 pandemic. This short commentary considers that possibility, i.e. that Brexit may lead firms to decide to change the location of their production plants (with the disinvestment that this entails).

Some articles have been published on this subject. Cumming & Zahra [5]; for example, tried to anticipate the consequences of Brexit on the barriers to trade and immigration. Wright et al. [6] analyzed the expected impact of Brexit on private equity and its implications on management research. Ijtsma et al. [7] found that the UK has become much less integrated into global production networks than other EU countries over the period 2000–14, and is almost unique among EU countries in that the domestic content of its exports increased over this period, many US and Asian multinationals and numerous European financial institutions set up establishments in the UK to take advantage of easy access to European markets, and of institutional and regulatory similarities.

This mentioned factors – and Brexit as a new constraint-highlight the significance and scope of production operations based on globalised value chains. Reconfiguration may be of interest for numerous reasons, e.g. basing more activities closer to home for strategic reasons (to ensure supplies of food and health products), for economic reasons (to guarantee local employment in specific areas and locations), for defence reasons (ability to produce certain devices) or for technology reasons (to protect certain know-how with a view to developing technology in areas of interest). For example, local production of wind or photovoltaic energy solutions can be defended on grounds of seeking to boost technological development in what will be a core field in the future.

Our proposal focuses on analysing the capability of technology elements for explaining re-location processes. We do this from a theoretical approach, but one which enables a reading to be taken at country level as to how the results will affect the countries with the highest technology levels in particular. Those countries will find themselves in a more favourable position to lead processes of repatriation of foreign investment. A company perspective is needed, in that repatriation processes must be explained in terms of logical business interests, but such companies operate within a technology context at country level which is highly relevant for these purposes.

2. Technology as a determinant factor in the potential for changes in value chains

The impact of Brexit will not be felt evenly across all sectors. Differences in the degree of exposure to trade and in regulatory implications mean that the plan set in place must carefully consider the specific problems of each sector of activity. In our opinion, technology is going to be a conditioning element in the ability of businesses to reconfigure the value chains in which they are involved. It is true that this challenge cannot be explained solely in terms of technology: it also has strong social and political dimensions. And it is obviously conditioned by the social and institutional context in which economic activities take place [8,9]. But we believe that technology is going to play a fundamental role in determining the shape of future value chains. Globalising value chains makes sense in terms of profits, so it can be expected to take different shapes in different product fields, and those product fields will change in accordance with the economic conditions that shape the chain.

Rosenberg [10] states that technology enables but also constrains. Value chains are globalised because the technology exists for them to do so. Powerful ICTs and fast, effective means of transport make this possible. Technology breaks up processes and makes it possible to synthesise components produced in geographically scattered locations into an end product.

Moreover, if technological potential is seen as a benchmark for production capacity and for the ability to make things, it is logical to assume that the ability of firms who take part in value chains to reshape those chains (acquiring a more central role or preventing themselves from being cut out of the chain depending on their technological potential) also depends on their technological potential. The firms with the greatest potential will be able to take on board a larger proportion of production work, while those with less potential and limited participation will try to defend that part of the production work which they carry out.

The dynamics of technology as it moves towards increasing automation and a decrease in the proportion of costs accounted for by wages is driving a relocation of manufacturing operations in developed countries (Industry 4.0). Economic rationality is responding to technological change by changing the geography of production: once-attractive locations are ceasing to be so.

Anticipating the effects and opportunities that result from Brexit requires a typology of technological problems that can contain a wide range of circumstances. It represents a natural approach to the problem of articulating the value chain that reflects the heterogeneous nature of reality.

Each technical solution entails a unique cognitive combination which, in this sense, defines a unique knowledge field with specific technological problems which is set to evolve in search of ways of improving performance in a cumulative fashion [11–13]. The search for solutions in the study of technological dynamics at sectoral level has given rise to an interesting body of literature that can be applied to our study. All industry-level analyses are applied to a widely heterogeneous universe, an analytical approach that seeks to establish a typology of behaviour patterns that enables us to explain the behaviour of the industry on the basis of identifying it with one or more of the profiles established. The characteristics of the supporting knowledge of an industry condition the characteristics of its technology dynamics [14]. There are no trends that can be generalised: their dynamics vary from one industry to another [15].

Our argument is based on the "technology regime" concept put forward by Nelson & Winter [16]; in which the patterns of technological behaviour that explain the evolutionary logic of each industry are different and specific to each. But given the heterogeneity of the set of products that make up the conventional definition of "manufacturing industry" [17], we use the concept of the "product field" to identify families of technical solutions to the same technology problem. For instance we refer to the products fields of railways, plant biotechnology products, etc.

The preferential areas of interest that we consider in order to interpret the potential for reconfiguring tasks in the value chain are the cognitive composition of the technical solutions involved and the make up of the technological dynamics associated with them. There are three variables that determine the cognitive content of a technical solution and that can help to determine how capable firms involved in value chain with particular characteristics in regard to those variables are of modifying their engagement:

a. Degree of novelty in the supporting knowledge bases of products and processes.

This variable determines the content and level of stability of supporting knowledge. The segmentation of the value chain requires some degree of stability in supporting knowledge. In the early stages the cognitive basis, grounded on basic knowledge, develops quickly, so that designs quickly become obsolescent [18,19], making it difficult to outsource components (which in any event belong to the latest generation); this calls for proximity and a setting with a high technology potential. The needs imposed by the dynamics of technology in fields which are in the early stages of development mean that high-level settings are required for outsourcing (technology services, latest generation components). Prudence in terms of future needs leads outsourcing to take place in settings which are high level, nearby but always limited.

Mature fields with stable technology solutions are conducive to greater segmentation. This is the case even in mature fields with highly dynamic cognitive bases, such as the automotive industry. This is made possible by the fact that there is a dominant design [13], because there is then a logic of stability to models that permits outsourcing over a four-year period (the lifetime of a model). With highly technologically complex designs and intense technological development, first-tier suppliers need sufficient technological potential to be able to adapt their designs with each change of model.

b. Degree of complexity of supporting knowledge: technological complexity and combinatorial complexity

It is technological complexity that determines how important scientific knowledge is in making up the knowledge base of designs. The scientific basis of technological knowledge takes us to the systemic nature of the process of technical creation, which results from information generated at basic, applied and development levels which needs to be worked on with the level of cognitive consistency to enable innovations to be generated [11,12,20]. Thus, research in the field of semiconductors cannot be explained without mastering the theory of the principles of solid-state physics, and the design of electric motors cannot be explained without prior knowledge of the principles of electromagnetic induction.

Secondly, all technical solutions result from a convergence of knowledge from different knowledge fields, which is used to actually create a product/process. This synthesis of knowledge in turn determines its own, unique knowledge field. The combinatorial complexity of that field increases in parallel to the number of knowledge fields involved in the synthesis [21]. Each technical solution defines a knowledge field made up of a combination of knowledge sets which enable the design in question to be formalised and constitute the cognitive basis on which innovation is deployed, seeking potential developments to improve performance in line with market indications [22]. Increased combinatorial complexity means more specific cognitive support for a technical solution and calls for technology potential capable of covering more fields of knowledge to take part in the technology dynamic.

Plant biotechnology comprises a set of product fields that can be seen as having a high level of combinatorial complexity, given that efficiently developing a new variety of seeds takes the joint efforts of geneticists, botanists, biochemists, entomologists and agricultural engineers. Research needs to take into account the conditions in the area where the seed is to be grown, the salinity, soil acidity, temperature, rainfall pattern, resistance to disease and plagues of insects, tolerance of herbicides, nutritional quality, etc. The technology potential that needs to be mobilised to carry out a project involves the use of knowledge brought in from other knowledge fields in the pursuit of a specific technical goal.

This high level of combinatorial complexity plays a major role in determining what countries have access to the outputs of such product fields, because firms in some countries will find it difficult to bring together the necessary technology potential.

c. Characteristics of the organisational model that governs the value chain.

The characteristics of the organisational model that describes the workings of an industry are an essential element of great importance in designs of a systemic nature.

The term "value chain" describes the full network of links established hierarchically between different companies, in which the dominant company synthesises the efforts of all participants in the end product, under the best possible cost conditions.

The dominant company defines the shape and form of governance of the fabric of production that makes up the value chain, seeking to make optimal use of the technology potential available in house and in the business and institutional context in which it operates, and therefore to maximise financial results. Each value chain has its own shape and a form of governance that depends on the cognitive composition of the technical solutions used and of the in-house and context-based technology resources.

Two relational areas that can affect what organisational model a value chain adopts can be distinguished:

1 **Technology cooperation**

Technology cooperation is the mechanism used by the dominant company to access and make use of the technology capabilities of its suppliers. It serves to enrich and configure the technology potential of the value chain as a whole, and thus to enable all the operations required to obtain the proposed outputs to be carried out.

The dominant company selects suppliers so as to outsource the manufacture of components that call for knowhow that it does not possess and redirect them in the direction desired for the end product of the chain, via a joint research project. Thus, the incorporation of sensors into vehicle engines has led car-makers to work with firms in the electronics industry, to which they outsource the manufacture of sensors and with which the cooperate on joint research projects to adapt those sensors to the specific operating conditions of motor vehicles (temperature oscillations, the presence of water, dust, interference with other magnetic field, induction from the electrical system, etc.). Any technological adaptation efforts made will always involve a process of joint research specific to the product/process in question.

This is a fundamental resource in the context of intense technological development, especially in products fields with high combinatorial complexity in which more new know-how originating from different fields is incorporated.

Technology cooperation is greater and more intense with companies that work in areas with more technology content. However, joint research is also subject to proximity constraints between parties, and is more intense when the tacit component of the knowledge used in the joint work is greater.

2 **Coordination of flows of goods**

The companies that form part of a chain need to build up joint representations for the exchange of products, so that they circulate effectively and in a coordinated fashion. This increased organisational complexity makes for better results, but means that the parties involved need to develop relational skills. This further reinforces the requirements for proximity between them.

For the most demanding organisational models to work (the motor vehicle industry is a case in point (Freyssenet, 2009; Frigant, 2008), there must be a just-in-time supply system and enough flexibility in

CRITICAL VARIABLES
A - DEGREE OF NOVELTY IN THE PRODUCT FIELD.
A.1 High degree of Novelty: technological development is territorialised, whatever its degree of complexity; outsourcing is limited and restricted to nearby settings. The instability of knowledge bases in settings with high-level scientific bases (new product fields) makes it hard to segment value chains and carry out outsourcing to maintain a long-term supply commitment. **A.2 Low degree of Novelty:** This means a stable scenario in terms of the cognitive composition of the technology solutions that make it possible to segment and outsource the operations that make up the value chain. This serves as a baseline scenario for the analysis in section B.
B - COMBINATORIAL AND TECHNOLOGICAL COMPLEXITIES
B.1 High combinatorial complexity plus high technological complexity There is a broad range of cases, including solutions with high levels of combinatorial complexity such as biotechnology developments which nevertheless involve relatively simple production processes in which there is limited scope for outsourcing. There are also solutions which are highly technologically complex but stable enough (a dominant design exists) in certain segments of the value chain where outsourcing is feasible and indeed desirable (automotive industry, aeronautics). There are systemic designs in which outsourcing is an essential requirement for competitiveness. The technological dynamics themselves reorganise the value chain: technology changes change the composition of suppliers (in the automotive industry suppliers from the electronics industry are becoming increasingly important). Organisational models are very important in these assumptions. **B.2 High combinatorial complexity plus low technological complexity** Cases with high combinatorial complexity are incompatible with designs with low technological complexity where the technical solutions used feature a lack of scientific knowledge. The widespread entry of science into products and processes renders such cases meaningless. It can be argued that the manufacturing of "period" cars and trains might be such a case, but it must be admitted that it would be of no significant commercial interest. **B.3 Low combinatorial complexity plus high technological complexity** (electronics, chemicals): there is a "core technology" associated with a knowledge field that features prominently in the cognitive composition of the technology solutions and determines the technology dynamic. The relevant designs can be segmented to a limited extent affecting the production of associated components and parts which are subcontracted based on cost.
B.4 Low combinatorial complexity plus low technological complexity (Parts & Components; in general almost all widely consumed products): less complex technological elements suitable for outsourcing either of components or of product manufacturing as a whole. Their few technological limitations make them conducive to the outsourcing of full production of products in search of cost advantages (textiles, footwear).

Chart 1. Typology of technological conditioning factors for the RECONFIGURATION of the value chain..

supply chains to enable them to react to last-minute changes in customer requirements without breaking the chain. Such systems further encourage physical proximity between participants.

In short, the technology component is a fundamental factor in determining the organisational forms under which value chains are run. Using the terminology coined by Gereffi, they run from the simplest forms (based on links in which there is little sharing of technological information), to "market" forms and on to "modular" and "relational" forms with links in which the technology content is greater [23,24]. If the technology component is taken a marker of increasing complexity, then an increase can be expected in those areas with a greater technology content, which use more complex (modular and relational) forms of governance that entail greater proximity constraints.

The combination of the values indicated in the cognitive composition of a technical solution enables a typology of different problems to be drawn up (Chart 1). It must be realised that a technical solution may be assessed overall on the basis of the variables indicated above, but at the same time it may be possible to segment it into production tasks which each have a specific cognitive composition. That segmentation must be interpreted in two ways: on the one hand in terms of the cognitive uniqueness of the task, and on the other hand in terms of its role in the overall technical solution.

3. Conclusions

Brexit may boost the process of relocation of operations that began in a small way some years ago driven by Industry 4.0 and most recently by the supply problems that came to light during the handling of the Covid-19 pandemic. But it is technology that will enable each industry to determine the specific potential for reconfiguring the tasks in the value chain to adapt them to new scenarios and economic rationales. We believe that the typology based on this technological perspective is significant because it could have considerable potential impact in defining business strategies in numerous industries and in orienting industrial policy in countries striving to acquire a more central role or to prevent themselves from being cut out of the global value chain.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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