The two faces of carbohydrates as sources of sugar-based innovations

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Mankind has for centuries exploited the characteristics of carbohydrates extracted from nature (e.g. wood, fibre, plant extracts, animal fat etc.). Key industrial applications have focused on plant polysaccharides such as cellulose, starch, pectins, algae, etc., for various applications largely because of their wide-ranging physicochemical functionalities. The carbohydrates, which are the constituents of these bio-based molecules, occur in many other forms in all living organisms where they play an essential role in many biological functions. They are studied by the biological discipline and have major potential to drive the bioeconomy. The exploration by glyco-scientists of the physicochemical and biological functions of carbohydrates will open-up innovative niches (Schot and Geels, 2008)[1]. The improvements in these scientific fields are contributing to industrial transformations (for biopharmaceutical industry, Niosi, 2017).[2]

This paper constitutes a first attempt to define the contours of a "glyco-economy". By "glyco-economy" we consider the production of all goods and services derived from carbohydrate molecules. The "glyco-economy" is a part of the bioeconomy by its ability to use renewable biomass instead of fossil raw materials but also to develop research and innovation in glycomics to produce a large variety of high added value glyco-based products used in diverse industries. To define the "glyco-economy", we analyze three various value chains starting at the extraction or production stage of carbohydrates until the final stage of glyco-based products. The three value chains are defined, based on the two main properties ('faces') of carbohydrates (physicochemical and biological) and the subsequent localization of the production system: i) the regional biomass (sugar, starch, wood etc.) supply chain exploits the physicochemical properties of carbohydrates; ii) the glycomics explores the biological functions of carbohydrates and; iii) the non-regional biomass (microbial, pectin, guar, chitin etc.) value chain exploits both properties. Biomass-based carbohydrate products have applications in various sectors (e.g. pharmaceutic, cosmetics, painting, agrofood, packaging). Glycomics have applications in drug discovery and development, vaccines and diagnostics. In the paper, we will focus only on carbohydrates based products throughout the value chain. We will therefore exclude lignin, protein, oil and intermediate molecules which are not carbohydrates.

We collected data from indirect sources (sectoral reports, etc.) and interviews with scientists, industry and institution (clusters, TTOs,…) representatives. We highlight the role of glycosciences as a potential driving force of innovation in various mature industries, at diverse stage of transition. We provide a thorough analysis of the market conditions, the industry characteristics, intellectual properties and regulation issues and the main actors and innovators in these different production systems. Our study provide dynamic pictures of

1 Schot, J., Geels, F. 2008. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. Technology Analysis and Strategic Management, 20 (5), 637-554.

2 Niosi, J. 2017. Imitation and innovation new biologics, biosimilars and biobetters. Technology Analysis and Strategic Management, 29(3), 251-262.

industries in transition, for firms diversely engaged in innovation. Our study shows that these three main value chains exhibit a high level of diversity in terms of innovations (substituting existing fossil fuel products vs. new products vs. disruptive innovations), and innovators involving very large companies with significant investments to dynamic SMEs entering the market as providers of new technologies.