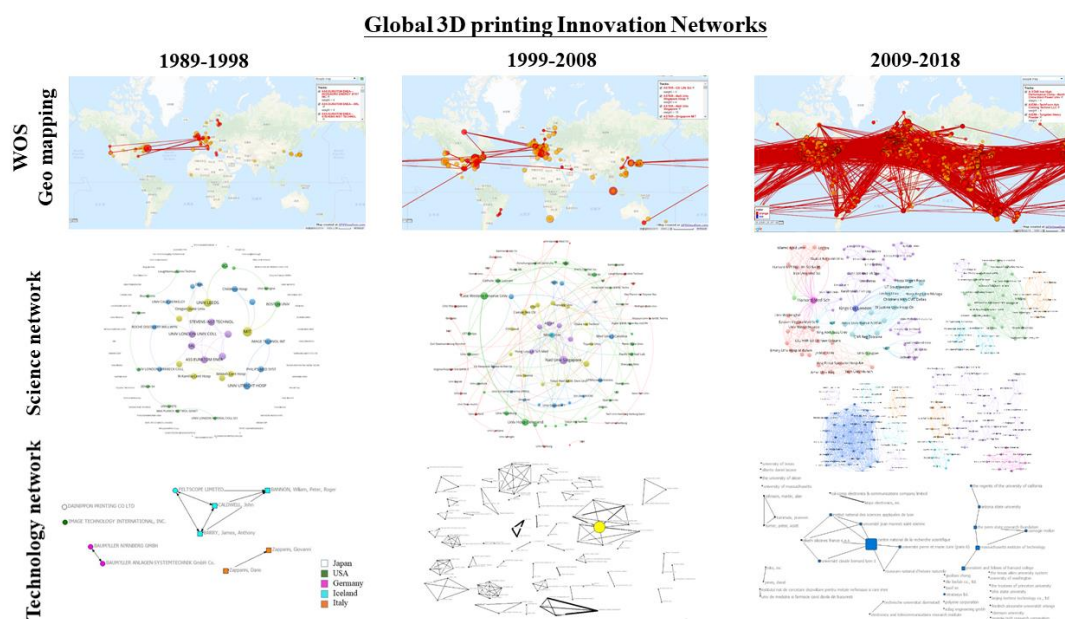# Abstract

Nowadays, innovation ecosystem has become a relevant research topic when addressing how emerging technologies have been developing. This relevance is mainly related to the fact that innovation ecosystem is critical for individuals, corporations, industries, regions, and countries. An ecosystem is constructed by different systems, such as, science (fundamental research), technology (patent), and business (products). In this context, 3D printing as one of the emerging technologies, has become a substitution for the contemporary mass production process and the related supply chains. Researchers analyze each sub-ecosystem individually or only by countries, such as China, so it turns out a lack of thorough study in the whole innovation ecosystem in the 3D printing sector. In this study, we collect 30 years (1989-2018) of data. Publications represent the development of fundamental research, patents represent the development of technology and the partnership represent the relationship between each companies. This study proposes a new framework which combines the idea of Xu et al. (2017) and Rotolo et al. (2017).

From the country level inside the three decades, USA has continuously been a leading country in 3D printing sector in the whole ecosystem. France shows a strong network between east Europe countries. China started to become a crucial player of 3D printing in 2009. On the other hand, by institute level, Massachusetts Institute of Technology (MIT), Centre National de la Recherche Scientifique (CNRS), and Chinese Academy of Sciences (CAS) are the anchor players that connect the three sub-ecosystems.

Regarding Taiwan, it has barely reached an outstanding position compared to those previous actors. However, Taiwan government started to increase support to 3D

printing sector since 2014 because of its strong ODM and OEM background. From 2018, it started to promote 3D printing medical devices by setting up a Factory of Intelligent Additive Manufacturing Medical Devices with Industrial Technology Research Institute (ITRI). Therefore, it is possible to conclude that National Tsing Hua University (NTHU), National Cheng Kung University (NCKU), and ITRI plays a critical role in Taiwan in 3D printing sector. However, current supportive policies are designed for each ecosystem. There is still a considerable missing part linking each sub-ecosystem, as the most important segment of the whole innovation ecosystem, which turns out to be done the least in the policy.

In conclusion, this study proposed a new framework combining the analysis of countries and institutes. Integrating the geographical data with bibliometric, patent analysis and at last the case study of enterprises in Taiwan for business ecosystem. Moreover, it gives the policy makers the suggestions that the importance of linking universities and research institutes to companies with the government's support help accelerate the commercialization pace and will be more competitive in the worldwide 3D printing sector.

Global 3D printing Innovation Networks

World	1989-1998	1999-2008	2009-2018
Science network	87 articles 88 nodes 40 edges Density: 0.0103 Degree centralization: 0.0364 Average degree: 0.909	718 articles 219 nodes 125 edges Density: 0.005 Degree centralization: 0.022 Average degree: 1.142	15211 articles
Technology network	131 patents 10 nodes 8 edges Density: 0.178 Degree centralization: 0.194 Average degree: 1.600	548 patents 128 nodes 148 edges Density: 0.018 Degree centralization: 0.045 Average degree: 2.313	7682 patents 654 nodes 498 edges Density: 0.0103 Degree centralization: 0.0364 Average degree: 0.909
Taiwan	1989-1998	1999-2008	2009-2018
Science network	0	31 29 nodes 15 edges Density: 0.036 Degree centralization: 0.0754 Average degree: 1.034	347 242 nodes 366 edges Density: 0.0125 Degree centralization: 0.1003 Average degree: 3.025
Technology network	0	21 patents 20 nodes 4 edges	424 patents 127 node 29 edges
Business network	-	-	96 nodes 72 edges Density: 0.016 Degree centralization: 0.167 Average degree: 1.500