Mathematics as public good

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- Theorems cannot be patented, but they have generated richness since ancient times (measurements using Pythagorean triples by the ancient Egyptians after the flooding of the Nile, accounting in ancient societies, counting animals, constructing buildings, dimensioning armies, the transition from abacus calculators to the Arabic system with zero, etc.).
- Mathematics constitutes a set of conceptual, artificial, and symbolic languages, highly developed for communication between human beings, the learning of which enables the resolution of economic problems vital to the functioning of a society. Therefore, **it has a significant presence in technology and the economy.**
- From the processing of production or consumption data on a computer to the logical reasoning used to justify one economic policy decision or another, mathematics is present in everyday reality, enabling the very existence of economic relations.
- It could be argued that without mathematical languages and concepts, individuals would not be able to carry out the vast majority of economic transactions that take place on a regular basis.

- In 2016, the European Commission launched a public consultation on mathematics in the Horizon 2020 Framework Program as a basis for the future Horizon 2020 work program with innovative mathematical content. Among other things, it states:
  - *"Two facts motivated this request: today's digital society depends on mathematics and algorithms; there is a vast pool of mathematical talent in Europe. The conclusión is that Europe can be first in mathematical applications for big data, computing, and especially HPC, to be first in modern science and innovation."*
- We will not discuss here the relevance of mathematics in its applications to physics, engineering, medicine, biology, social sciences, etc., but rather we will show **how the economic value of mathematics can be measured and how it can contribute to the development of small countries in Europe.**

- The **economic nature of mathematics as a semi-public good** makes it difficult to measure using the logic of National Accounting, a problem that is magnified when one considers its capacity to derive positive externalities or benefits for society as a whole, which does not necessarily participate in its production.
- However, **its status as a private good characterized by the appropriable benefits that its use extends to economic activities allows for a partial approximation of its economic weight or relevance.**
- It should not be forgotten that the participation of mathematics in productive activities is cross-cutting, as it affects all sectors and intervenes in the different phases of the production process of goods and services. From the design, modeling, simulation, and prototyping of products, to the optimization of production and organizational processes and data analysis.
- Facilitating the generation of benefits or incentives for the exploitation of mathematics in its dimension as a private good necessarily require **public intervention, among other reasons, to reduce learning costs.**

	EXCLUSION	NON-EXCLUSION
RIVAL	**Private goods** Clothing Food goods	**Free-access common goods** Public parks International waters **Congestion goods** Toll-free highways Public education
NON-RIVAL	**Club goods** Pay TV Sports clubs	**Pure public goods** Defense Research

Characteristics of private and public goods

Mathematics as a:

- **Semi-public good**
  - As it is not an appropriable resource, there is no market value that reflects its true utility to society.
- **Private good**
  - Taking into account the appropriable benefits for agents who possess knowledge of the fruits of mathematical research.
  - From this perspective, mathematics can be understood as an asset held by individuals, which requires an initial investment in learning and which, throughout the life of the individual who acquires it, generates a series of tangible benefits.
  - Thus, individuals face the dilemma of “investing” effort in mathematical learning, depending on the balance between benefit flows and costs. When these benefits are easily predictable and greater than the costs, individuals will invest in their mathematical education.

- The Internet revolution has positioned mathematics as a fundamental input for production, insofar as services have increasingly incorporated both physical-technological capital based on mathematics (information and communications technologies, software, electronic devices, etc.) and mathematical human capital.
- Mathematics is at the base of the pyramid of ideas and knowledge that have productive applications.
- Modern theories of economic growth link the long-term evolution of per capita income to the rate at which knowledge accumulates, which leads to increases in labor productivity.
- This is strategic knowledge that will enable a country economy and its business fabric to take advantage of the opportunities arising from the technological revolution associated with robotization and artificial intelligence.

European comparison: employment

- Studies on the impact of mathematics in the United Kingdom and the Netherlands show that the proportion of mathematics in paid employment in France (12% in 2012) is comparable, although slightly higher, to that in the United Kingdom (10% in 2010) and the Netherlands (11% in 2011).
- The study conducted in Spain shows that the proportion of mathematics in paid employment in 2016 in France (12%) is twice that in Spain (6%).
- The Spanish economy continues to employ a relatively small number of workers in database, financial services, and software design jobs, where mathematics has a major impact.

European comparison: contribution to GDP

- Mathematics contributes 17.6% of France's gross domestic product (GDP) in 2019, or €2.169 billion.
  - Value creation linked to mathematics grew faster than added value in France from 2012 to 2019, at an average annual rate of 3.7% over the period 2012-2019, while the added value of the French economy increased by 2.1% over the same period. During the period 2016-2019, mathematics contributed even more to value added.
  - The share of mathematics in French GDP increased by 1.8 percentage points in seven years, from 15.8% of GDP in 2012 to 16.7% in 2016 and 17.6% in 2019.
- The share of mathematics in value added in France is similar to that of the United Kingdom (16% in 2010) and higher than that observed in Spain (10% in 2016) and the Netherlands (13% in 2011).

- For all this to be possible, it would be advisable:

  (i) for mathematics to take on a leading role in the educational model,

  (ii) to improve the link between the academic world and business,

  (iii) to promote research and applied mathematics,

  (iv) and to raise awareness in the business world of the usefulness of mathematics in the various stages of the production process.