Chapter 2. Mechanism and Natural Law: From Physics to Economics

I. Introduction

In Chapter 1, the first two conceptions of the economy (substantive and formal) dispense with prices, which can be introduced at a second stage. By contrast, the third conception — which is not exclusive of the first two — defines an economy through coordination via prices. Prices are assumed to be determined by a *mechanism, independent of individual or collective wills*. The notion of mechanism first appears in physics, before being imported into economics.

Chapter outline.

First stage. The epistemology of classical physics. We start from Aristotle's physics, to which Galileo opposes a new physic. Galileo (late 16th, early 17th century) breaks free from Aristotle (4th century BC). His method is described as rationalist. Note that the term 'rationalism' was not claimed by Galileo himself; it was attributed to him in the 19th century. Rationalism, developed first by Galileo and then by Descartes to construct classical physics — in opposition to Aristotle's physics — understands *the physical world as a mechanism*, i.e., as *a process that escapes intentions*. 3 characteristics.

- This mechanism is understood through *mathematics*, that is, through the *quantification of the physical world*.
- *Knowledge* of the mechanism *starts from a thought experiment*, that is, an imaginary experiment.
- The method that gives access to how the mechanism works and to its results is a deductive method.

  ⇨ Understanding the physical world as a mechanism, made possible by a threefold condition (thought experiments, mathematization of the world, and deductive method). From that, it is possible to establish the *natural laws of the physical world*.

Second stage. Galileo's rationalism had a decisive influence on the birth and development of economic thought. Economics imported the notion of mechanism from the physical world into the social world.

It claims to understand the social world through similar conditions (thought experiments, mathematization, deduction) in order to bring to light an economic mechanism that operates independently of human wills. Economics thus claims to establish the natural laws of the economy — the natural laws of the social world — just as physics states the laws of the physical world.

II. The Laws of Nature in Physics: The Galilean Revolution and the Notion of Mechanism

1. Motion in Aristotle's Physics

i) Physics and Astronomy

- Physics studies motion. But there two types of motion: in the *sublunary* (under the moon, on earth) world; here is the field of physics. Astronomy studies motion in the supralunary, or superlunary (the sky) world. The sublunary and supralunary worlds do not obey the same laws.

- In the sublunary world, the aim is to study the motion of *natural beings* = beings whose motion is internal, unlike objects made by man, whose motion comes from elsewhere. The natural beings differ from the artificial beings: if you bury a bed and it starts to sprout, it does so as wood, not as a bed. Beds do not grow out of the ground like pumpkins — it is the worker who makes them. Here we are interested in the motion of beings like pumpkins, whose motion does not come from the hand of man.

- For Aristotle, the word 'motion' designates changes of state in determinate beings. There are many different types of motion. Local motion, for example, is not seen as a distance covered in a given time, or as a velocity (speed). In Aristotle, types of motion *differ qualitatively*: the motion of a living being may be that of a bird, of a fish, of a dog, of a human, etc. There are different types of motion. For a non-living being, the motion may also be different: the motion of a stone is a motion toward the center of the world; the motion of fire is towards the sky. The bodies that move belong to different substances; these bodies differ not only in quantity (their motion is fast or slow) but in quality.

ii) Sense Experience and Finalism

- Aristotle sets out a physics derived from sense experience. In the Physics, he observes that fire rises and that stone falls: sense perception (sight) indicates qualitative differences between bodies. Aristotle concludes that bodies do not obey uniform laws but behave differently — because they appear to behave differently, as far as we can observe. They behave according to their intrinsic qualities: lightness for fire, heaviness for stone.

- From sense perception (sight), Aristotle infers (explains) the main cause of motion: it is the final cause, internal to the object: if, as we see, the stone falls "all by itself," without constraint, it is because *its end is to fall*. *This end comes from its nature, which is to reach the body's natural place*. This place differs according to the bodies:

> "The transports [=motions] of simple natural bodies such as fire, earth, and the like, indicate (…) that place has a certain power: indeed, each is carried toward its own place if nothing obstructs it, one upward, the other downward (or else to the right, to the left, etc.) The upward (…) is the place to which fire and the light are carried, and likewise the

> downward (…) is the place to which heavy and earthy things are carried" (Aristotle, Physics, Book IV, I, 208a-208).

Things, that is, bodies here, cease their motion once they have reached their natural place. This natural place differs according to the nature of things (according to their substance). Bodies tend toward rest, but they cannot as long as they have not reached their natural place.

- Motions depend to a large extent on the nature of the thing (= the body) that possesses them. Motion is designated by reference to the final state toward which the subject tends.

  There is a difference in the natural motion of the light bodies, and of the heavy bodies. Light bodies have an upward rectilinear motion. It is the motion by which fire reaches its own place, its natural place, and fully realizes its essence. Motion finds its reason in the substance itself: the motion of a runner on a race has its reason in his will to win the prize, the motion of fire has its reason in the nature of fire, whose natural place lies in the upper regions.

  ⇨ Summary: physics (defined as the study of the motion of sublunary things) is the study of the reciprocal actions that take place between the elements. All motions have their final cause — that is, their true cause.

Aristotle's explanation of motion is in accord with sense perception:

> "If Aristotle's 'demonstration' was judged so conclusive, it is because it ultimately amounted to getting reason to accept the most elementary, and therefore the most tenacious, indications of sense experience" (Clavelin, 1996, p. 394).

Indeed, we see things move differently according to their nature and come to a stop as if by themselves, as though they had reached an end => Aristotle's physics is inductive: it starts from sense experience.

2. Galileo: The Law of the Conservation of Motion and the Notion of Mechanism

i) A Scientific Revolution

- Regarding the birth of modern science, one usually speaks of a "scientific revolution," meaning by that the shift from the geocentrism of Aristotle and Ptolemy to heliocentrism, presented as a hypothesis by Copernicus and as a thesis by Galileo. But this reading has since been qualified.

- There was indeed a scientific revolution, but less on the side of astronomy than of physics, as the science of motion. It is the geometrization of motion, or the mathematization of physics, carried out by Galileo, that is decisive and justifies speaking of a "scientific revolution." This geometrization or quantification of motion interests us because it will serve as a model for economic thought. To geometrize motion is to found a physics radically distinct from that of Aristotle.

ii) The Principle of Inertia Contradicted by Sense Experience

- Galilean physics substitutes for Aristotle's physics the *principle of inertia* = a principle for explaining the motions of bodies according to which bodies move not according to their intrinsic qualities, but solely under the effect of an external mover (or motor, or driver), and conserve the motion transmitted by that mover. This principle for explaining the motions of bodies is not the finality of the bodies. This is the idea of the principle of inertia: on the one hand, a force is necessary to bring a motion; on the other hand, no force is necessary to ensure the conservation of motion in the absence of opposing forces.
- The problem: how, then, do we explain that bodies, once in motion, come to a stop, as if they stopped spontaneously? Aristotle answered this question by stating that the stone stops rolling because it has reached its natural place. Galileo answers it by maintaining that the stone stops rolling only because of an external cause. But this external cause is not perceptible to the naked eye: it is external friction, air friction, that acts on the stone, that slows its speed until the motion stops. In the absence of this friction, the stone would not stop rolling. The principle of inertia (bodies move only under the effect of an external mover and conserve their motion) is not observable, because the friction of the air is not always visible.

iii) The Thought Experiment: The Frictionless Machine

- The physics that states this principle cannot rely on sight. It must therefore rely on a fiction: the fiction of a world without friction. This fiction is given by a thought experiment, or mental experiment = fictive experiment. This mental experiment is not only an abstraction. It is a fiction, that is, it requires the imagination.
- One example of a mental experiment is the frictionless machine. It is not a concrete machine. It is a machine that Galileo imagines in order to eliminate friction in thought — the only way, in his view, to formulate the law governing the motion of bodies. To facilitate his reasoning, he proceeds through a concrete experiment, that of an inclined plane, perfectly polished, on which he rolls spheres that are also polished.
- He is not the first to use an inclined plane in physics, but he is the first to see it as an approximate illustration of a frictionless machine, which cannot exist in reality. This inclined place, which is not a fictive experiment but a real experiment, has conditions that offer the least resistance to the motion of the spheres. The frictions of the concrete world are reduced to a minimum.
- This concrete experiment makes it possible to show that, if the angle of inclination is gradually reduced until it becomes zero (the plane is no longer inclined), falling bodies do not tend toward rest, as Aristotle thought, but display an indifference to both rest and motion.

- This is a first step toward the principle of the conservation of motion: the frictionless machine refutes the Aristotelian thesis, according to which heavy bodies are moved by an internal finality and tend toward rest once they have reached their natural place. For Galileo, the balls tend no more toward rest than they tend toward motion: their motion is explained by no internal finality.

iv) Sense experience and Deceptive Perceptions

- Experience = sense experience, what is perceived by senses (here, sight, and experience is observation). Different from experiment (concrete or fictive). Scientific explanations come from experiment and get rid of sense experience
- Since Galileo, we have learned to observe and measure the friction that obstructs the conservation of motion and causes bodies to stop as though spontaneously, when this is not in fact the case.
- Observation is not dismissed, but it can be called into doubt because our senses are deceptive.

> "There is no shortage of occasions on which our senses, in their first apprehension of the facts, can err and therefore need to be corrected by means of sound reasoning" (Galileo).

Perception is deceptive; it makes us believe what is not so: that the stone stops spontaneously, that the stick plunged into water is broken, that the sun revolves around the Earth. This is why we need thought experiments that give access to the true explanation. This does not prevent us from trying to perceive otherwise than through initial experience, which is deceptive, and for example from trying to measure friction. However, if we can perceive and measure friction, it is because we already had the idea that it is friction that stops bodies, and not their finality. This idea does not come from sense experience, which is primary. It is the fictive thought experiment that produces the true explanation and that gives access to a perception that is not immediate or spontaneous, but is mediated by an understanding of what is not immediately visible. The measurement of friction passes through such mediation.

- So the true explanation Galileo provides does not go against all experience and all perception, since not every perception or experience is deceptive. But it gives access to perceptions (observations) that are not immediate and not deceptive.

⇨ Summary: the classical physics inaugurated by Galileo presents three characteristics that we will find again in economic thought.

a) It is mathematical because it states a principle for explaining motion that holds for all bodies. The differences between bodies are quantitative, not qualitative. Hence a mathematical expression is possible.

b) It relies on a mechanism, as opposed to Aristotle's finalism: Aristotle's finalism explained the motion of bodies by their end (= their final cause: reaching their natural place). Galileo's mechanism is a device whose motions are blind, because they result from no finality of the bodies.

- Mechanisms can be machines built by man, either concretely (the inclined plane) or in the imagination (the frictionless machine).
- They can also be natural mechanisms, that is, mechanisms that exist in nature and whose workings we seek to understand. Understanding the mechanisms built by man makes it possible to explain the mechanisms that exist in nature.
- The frictionless machine, an imagined mechanism, makes it possible to think the mechanism truly at work in nature, which is not perceptible to the naked eye: the principle of inertia.

c) Galileo's physics departs from sense experience and induction, and relies on fiction and deduction.

- The thought experiment is essential because it makes it possible to understand what the concrete experiment of the inclined plane fails to show, since on an inclined plane friction is never zero and the balls always eventually stop.
- The mechanism at work in nature is expressed in the laws that govern motion (the principle of the conservation of motion = principle of inertia). This knowledge is reached by deduction, starting from the fiction of the frictionless machine, from which the motions of bodies are deduced rather than observed.
- It would be a mistake to set science founded on mathematics, on the one hand, against fiction or imagination, on the other. For precisely, the mathematization of reality presupposes stepping outside experience — here, it presupposes recourse to a fiction:

> "To mathematize (…) is first of all to replace qualitative concepts with quantitatively definable concepts and to transpose into physics the deductive order of geometry. (…) it is also to break (…) with sense experience, to abandon the complexity and contingency of concrete situations in favor of type cases as general as possible (…); in short, to mathematize is to idealize" (Clavelin, 1996, p. 177).

- The break with Aristotelian physics requires stepping outside sense experience. The real experiment (the concrete inclined plane) serves Galileo only as an occasion for thought. The idea of the frictionless machine, and the results it produces, is prior to concrete experience and can dispense with it.