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Newton's real influence on Adam Smith and its context

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While Newton's influence on Adam Smith has been widely acknowledged, there is scant research on the actual nature of this influence. This paper sums up a line of investigation delving into this issue. After a short introduction, it is argued that Newton's methodology is more complex than a merely positivistic interpretation. Then the context of Newton's influence during the turn of the seventeenth century and the eighteenth century is assessed. It will be suggested that a British (and particularly Scottish) interpretation of Newton diverges from the French reading of his legacy. The final section analyses Smith's understanding of Newton, arguing that the father of economics was a sophisticated interpreter. The intellectual context of what the Scottish Enlightenment made of Newton, and how he was interpreted, may have played a major role in explaining how Smith understood Newton's legacy.

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JEL classifications: B12, B13, B40, B41

1. Introduction

The impact of Newton's methodology and his revolutionary discoveries during the eighteenth century encompassed not only natural philosophy and the take-off of modern physics, but also, although to a lesser extent, our understanding of moral philosophy. For example, in query 31 of his *Opticks*, in the last paragraph of this book, Newton declared '[a]nd if natural Philosophy and all its Parts, by pursuing this Method, shall at length be perfected, the Bounds of Moral Philosophy will also be enlarged' (Newton, 1979 [1704], p. 405). This statement had great influence on moral philosophy, and *a fortiori* in political economy. While Newton's influence on Adam Smith has been widely acknowledged, its treatment has been rather scant.[1] If there is agreement on Newton's actual influence on political economy in general, and on Smith in particular, what has gone relatively

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[1] For example, in the 2003 Annual Supplement of *History of Political Economy*, entitled *Oeconomics in the Age of Newton*, with the notable exception of Schabas (2003), scant references to Newton's actual influence in political economy can be found. Although important research of Smith and Newton has been developed by Schliesser (2005A, 2005B), Cremaschi (1981, 1984, 1998) and Lazaro (2002), what has gone relatively unnoticed is the real nature of what can be termed Smith's Newtonianism. (see Montes 2003)

unnoticed is the real nature of what can be termed as Smith's Newtonianism. This paper will sum up a line of research on the relationship between Smith and Newton.

The irrefutable character of *Principia* (*Philosophiae Naturalis Principia Mathematica*, 1687), with its laws of motion and the universal law of gravity 'derived from phenomena', and the spectacular nature of Newton's *Opticks* (*Opticks: or, a Treatise on the Reflexions, Refractions, Inflexions and Colours of Light*, 1704), with its experimental results and its many speculations, influenced the way modern savants would think about the world. Although David Hume has been considered as paradigmatic regarding Newton's influence, George Turnbull (1698–1748) was perhaps the first Scottish intellectual to explicitly invoke Newton for his moral investigations. In his *The Principles of Moral Philosophy* (1740) Turnbull states that 'we must enquire into moral phenomena, in the same manner as we done into physical one', recalling Newton's remark in query 31 of his *Opticks*. David Hume, explicitly claiming to be following Newton's 'experimental method',[1] would advocate his moral philosophy as developing the 'science of man'. The inherent complexity of Newton's 'experimental philosophy' engendered multiple interpretations during the eighteenth century. Adam Smith was no exception within this context. But his understanding of Newtonianism, as this paper will argue, was indeed exceptional, and pervaded by a distinctively British, but particularly Scottish, context.

The next section of this essay will discuss the nature of Newton's method, arguing that his intentions were multifaceted and his methodology quite different from a positivistic interpretation of his legacy. A careful reading of *Principia*, the queries of his *Opticks*, and part of his extensive collection of private manuscripts uncover a picture that broadly differs from the Victorian image of Newton as the father of the 'Age of Reason'. The third section will examine how Newton's methodology was assimilated at the turn of the seventeenth century, suggesting that the implementation of different methodological positions became associated with different scientific agendas. In particular, I suggest that the impact of Newton's spectacular discoveries in Book 3 'Of the Systems of the World' epitomised a positivistic interpretation of Newtonianism which principally evolved in France, contrasting with a British (and particularly Scottish) assimilation of his legacy, which prioritised an empirical and more realistic approach. The fourth section will analyse Smith's understanding of Newtonianism. It will be shown that Adam Smith, especially in his famous essay *History of Astronomy*, was quite familiar with Newton's actual methodology and that he relied upon a distinctively Scottish interpretation of Newtonianism. Finally, the paper will end with some brief conclusions.

2. On Newton's Newtonianism

In 1936, Viscount Lymington, a descendant of Newton's niece, Catherine Barton, sent to Sotheby's a trunk containing a bunch of Newton's manuscripts. They amounted to nearly 3 million words, and were split into 329 lots for auction. John Maynard Keynes managed to buy, rather cheaply, 120 lots, and he gradually reassembled more than one third of the

[1] Newton's methodology was well known to Hume who in his second Enquiry (*An Enquiry Concerning the Principles of Morals*, 1751), treating the subject of justice, finishes this important section appealing to 'Newton's chief rule of philosophizing' (Hume, 1998 [1751], p. 98). Moreover, the subtitle to his monumental *Treatise of Human Nature* reads *Being an Attempt to Introduce the Experimental Method of Reasoning into Moral Subjects* (1739–40). His introduction to this book finishes with the following sentence: 'Where experiments of this kind are judiciously collected and compar'd, we may hope to establish on them a science, which will not be inferior in certainty, and will be much superior in utility to any other of human comprehension' (Hume, 2000 [1739–40], p. 6).

collection, currently at Cambridge University (on this fascinating story see Spargo, 1992). Keynes, after reading the many manuscripts, found that Newton was quite different from the Victorian image that had deified him as the father of the 'Age of Reason'. He wrote in his posthumous 'Newton, the Man' (Keynes, 1972, pp. 363–74):

> Newton was not the first of the age of reason. He was the last of the magicians, the last of the Babylonians and Sumerians, the last great mind which looked out on the visible and intellectual world with the same eyes as those who began to build our intellectual inheritance rather less than 10,000 years ago. (Keynes, 1972, p. 364)[1]

Certainly Keynes was very impressed by what he read. In fact, though Newton's reputation was built upon his scientific discoveries in mechanics, cosmology, optics and mathematics, he spent much energy dealing with alchemy, theology, prophecies and ancient wisdom. This was simply ignored. No wonder that David Brewster, in his classical biography *Memoirs of the Life, Writings, and Discoveries of Sir Isaac Newton* (1855, which was an expanded version of his 1831 *The Life of Sir Isaac Newton*), could not understand 'how a mind of such power, and so nobly occupied with the abstractions of geometry, and the study of the material world, could stoop to be even the copyist of the most contemptible alchemical poetry' (Brewster, 1855, pp. 374–5). This unknown facets of Newton had remained quite dormant as Great Britain exploited Newton's image 'as the first and greatest of the modern age of scientists, a rationalist, one who taught us to think on the lines of cold and untinctured reason' (Keynes, 1972, p. 363). Indeed, only after Keynes's path-breaking essay did different biographies begin to offer a more detached and objective account of the real Newton.[2]

Throughout his life Newton reluctantly disclosed his 'public science', but he was extremely cautious regarding his 'private science'. The former was manifest in his positions as Cambridge Lucasian Professor, Master of the Mint and President of the Royal Society. But the latter was hidden from public opinion. Only a few friends knew that he was a devout alchemist and a heretic that privately denied the Trinity.[3] Recent studies on Newton have recognised the importance of 'private science' for Newton, though there is no general agreement on the extent of its influence. In particular, his alchemical pursuits have been the source of much debate. After Dobbs' publication of *The Foundations of Newton's Alchemy: The Hunting of the Greene Lyon* (1975) and then *Janus Faces Genius: The Role of Alchemy in Newton's Thought* (1991), there is no discussion about the influence of

[1] It is interesting to note, as a curiosity, that Keynes also considered that Newton's 'secret heresies and scholastic superstitions' were 'wholly devoid of scientific value' (Keynes, 1972, p. 370). Although he made a good deal buying the manuscripts rather cheaply, according to him they 'have, beyond doubt, no substantial value' (Keynes, 1972, p. 368). Nowadays the relevance of this 'heresies' for Newton's scientific programme are widely acknowledged. Its importance is simply a matter of degree. There is no doubt, however, of the economic value of Newton's manuscripts. In the year 2001 Cambridge University Library acquired the Macclesfield Collection for £6 million. Ironically, in 1888, the University Library had returned Newton's manuscripts as they 'lacked scientific value'.

[2] The early accounts of Newton's life are by Bernard le Bovier de Fontenelle who published *The Elogium of Sir Isaac Newton* in 1728; William Stukeley, Newton's friend and follower, who wrote *Memoirs of Sir Isaac Newton's Life* in 1752, and Sir David Brewster's two volumes *Memoirs of the Life, Writings, and Discoveries of Sir Isaac Newton* (1855). The latter remained the classical biography of Newton as the father of the 'Age of Reason'. Although many biographies of Newton have been written since Keynes essay, in my view Richard Samuel Westfall's *Never at Rest: A Biography of Isaac Newton* (1983), remains the best account (a condensed version entitled *The Life of Isaac Newton* was published in 1993). Manuel (1968) gives a rather Freudian reading of Newton, Hall (1992) is also an excellent biography, and recently White (1998) and Gleick (2003) have published good and agreeable accounts of Newton's life.

[3] Actually Newton was an Arian, and any form of unitarianism was excluded from the Toleration Act of 1689. On theology and alchemy, Newton's correspondence with John Locke is extremely interesting.

Newton's alchemical studies for his system; it is simply a matter of degrees.[1] Newton was exceptionally well read in alchemical literature, and was also an eximious practitioner. He was a voracious reader of the Scriptures and theological treatises, and its influence in his system cannot be denied.[2] He was also convinced that ancient sages knew the law of gravity, and spent much time studying the prophecies in the Book of Daniel and the Book of Revelation.

It is evident that Newton conceived his speculations about the nature of matter relying on his alchemical, theological and ancient wisdom knowledge. As Patricia Fara pesuasively put it: 'for him gravity, alchemy, and God were intimately linked through his ethereal speculations. Newton's alchemical pursuits were not ancillary to his natural philosophy but rather formed an essential part of his religious endeavor to study God's activities from as many aspects as possible' (2003, p. 501). But, what is the nature of Newtonianism? And, was there an official Newtonianism? To answer these questions, we must first investigate what Newton really said about his methodology. His actual method evinces Newton's original position on scientific progress.

In addition to Newton's many intellectual facets and activities, *Principia* (1687)[3] and *Opticks* (1704)[4] are the most known public sources for understanding Newton's method. Regarding his *magnum opus*, *Principia*, its complete title *Philosophiae Naturalis Principia Mathematica* much resembles Descartes's *Principia Philosophiae* (1644). As Newton knew quite well, Descartes's 'theory of vortices' was completely mistaken—there was no mechanical cause behind gravity. And he availed of this error: Newton's *Principia* explicitly pretends to supplant Descartes's enormous influence. The contrasting physical and metaphysical assumptions of Descartes's *tourbillons* against Newton's law of gravity, were the origin of a longstanding debate.

In the preface to *Principia*'s first edition Newton states:

> it has seemed best in this treatise to concentrate on *mathematics* as it relates to *natural philosophy* . . . And therefore our present work sets forth mathematical principles of natural philosophy. For the basic problem of philosophy seems to be to discover the forces of nature from the phenomena of motions and then to demonstrate the other phenomena from these forces. It is to these ends that the general propositions in books 1 and 2 are directed, while in book 3 our explanation of the system of the world illustrates these propositions. For in book 3, by means of propositions demonstrated mathematically in books 1 and 2, we derive from celestial phenomena the gravitational forces by which bodies tend toward the sun and toward the individual planets. Then the motions of the planets, the comets, the moon, and the sea are deduced from these forces by propositions that are also mathematical. If only we could derive the other phenomena of nature from mechanical principles by the same kind of reasoning! For many things lead me to have a suspicion that all phenomena may depend on certain forces by which the particles of bodies, by

[1] On Newton and alchemy see especially Figala (1977, 1992 [1984]).

[2] As Margaret Jacob has perceptively put forward: 'the religious Newton was never at odds with the scientific Newton; quite the reverse' (1988, p. 90). *Principia*'s *General Scholium* and *Opticks*' queries, as will be seen, are good examples of Newton's dialectic between theology and natural philosophy.

[3] The first edition was published in 1687 by the Royal Society, thanks to Edmond Halley. The second, edited by Roger Cotes, in 1713, and the third, edited by Henry Pemberton, was published in 1726. The first English translation of Newton's *Principia* was made by Andrew Motte, and published posthumously in 1729. A revised version, by Florian Cajori, was published in 1934. Bernard Cohen and Anne Whitman published in 1999 the definitive complete translation of *Principia*, preceded by Cohen's excellent *A Guide to Newton's Principia*.

[4] The first edition of Newton's *Opticks* was finally published in 1704, 30 years after it had been written, just a year after the death of his lifelong rival Hooke. In *The Advertisement* to the first edition Newton explains that in order to 'avoid being engaged in Disputes' he had not published this work. A second edition in Latin, translated and prefaced by Newton's friend and staunch advocate, Samuel Clarke, was published in 1706, followed by a second English edition published in 1717.

causes not yet known, either are impelled toward one another and cohere in regular figures, or are repelled from one another and recede. Since these forces are unknown, philosophers have hitherto made trial of nature in vain. But I hope that the principles set down here will shed some light on either this mode of philosophizing or some true one. (Newton, 1999 [1687], pp. 381–3)

Three main points are worth exploring after reading this passage, which is part of the first paragraph of *Principia*'s preface. First, *Principia* immediately calls our attention to its revolutionary 'mathematical method' (see Cohen, 1980); it was purposefully written in 'the mathematical way'. Newton, at the beginning of Book 3 'The System of the World', declared that he had 'composed an earlier version of book 3 in popular form, so that it might be more widely read' but that in order 'to avoid lengthy disputations, I have translated the substance of the earlier version in a mathematical style, so that they may be read only by those who have first mastered the principles' (Newton, 1999 [1687], p. 793). After his early debate with Hooke, Newton became obsessed with the reception of his findings. Reportedly he told a friend that he abhorred contentions, having made 'his *Principia* abstruse' just 'to avoid being baited by little Smatterers in Mathematicks' (quoted in Westfall, 1980, p. 459). Second, Newton exposes his methodology as going from 'phenomena of motions' to 'the forces of nature', in order to deduce other phenomena from these forces. This is a clear statement of Newton's analytic-synthetic method, a theme that will be discussed soon.

The third point: after explaining the content of *Principia*, and the need for mastering 'the general propositions in books 1 and 2' before understanding the 'system of the world', Newton suspects the existence of 'certain forces' of attraction occasioned 'by causes not yet known'. These 'unknown forces' gave Newton much trouble, as his system was criticised as being dependent on some 'occult causes', much resembling the discredited Aristotelian-scholastic tradition. But he finishes this long paragraph with the hope of shedding some light either by this mode of philosophising or simply by giving place to 'some truer one'. The latter concern for truth has two important implications. Newton was not only relying in his method as the final truth, but his quest was embedded in a sincere desire to uncover the real nature of things. He also presents his findings as part of a process. This evinces a scientific realism that allows further scientific progress.

The *General Scholium*, which was Newton's reaction against theological accusations, was explicitly intended to obliterate the Cartesians and the adherents of 'mechanical philosophy'.[1] Newton justifies his attempt: 'to treat of God from phenomena is certainly a part of *natural philosophy*'.[2] Using the simile of the blind man who has no idea of colours, perhaps having in mind the famous case of Nicholas Saunderson (1682–1739),[3] Newton

[1] At the outset Newton immediately states '[t]he hypothesis of vortices is beset with many difficulties' (Newton, 1999 [1687], p. 939) and then he bluntly declares against Descartes and 'mechanical philosophy' that 'regular motions do not have their origin in mechanical causes' (Newton, 1999 [1687], p. 940). On the former it must be underlined that Newton refers to Descartes's theory of vortices dismissively as a 'hypothesis', a word that became anathema for Newton after Hooke referred to his findings in *Opticks* as a 'hypothesis' and then Huygens described Newton's optical discoveries as a 'probable hypothesis'. Newton's reluctance to publish his work *Opticks* and his famous dictum 'hypothesis non fingo' (Newton, 1999 [1687], p. 943) were only a natural consequence of this context. Alexander Koyré perceptively pinpointed that hypothesis became for Newton 'toward the end of his life, one of those curious terms . . . that we never apply to ourselves, but only to others' (1965, p. 52). However, it must be acknowledged that Newton himself 'feigned' and also 'framed' hypothesis throughout his life.

[2] It is worth noting that in the second edition Newton initially referred to *experimental philosophy*, but for the third edition he broadened this concept changing it into *natural philosophy* (Newton, 1999 [1687], p. 943).

[3] Saunderson contracted smallpox when he was one year old, losing his sight and his eyes. He actually met Newton, and his circle while he was at Cambridge. William Whiston became Lucasian Professor of mathematics after Newton in 1703, and after he was removed from his chair for denying the Trinity, Saunderson became his successor in 1711.

not only epitomises God, but uses this assumption to justify his existence. He uses the same assumption about gravity: it does not matter that the cause of gravity is unknown, what really matters is that gravity 'exists' (Newton, 1999 [1687], p. 943). This constitutes Newton's departure from the prevalent 'mechanical philosophy' tradition, initiated by Galileo, and followed by Descartes and Huygens, which required a contact mechanism as causing any force. Part of this celebrated and fundamental paragraph is worth reproducing:

> Thus far I have explained the phenomena of the heavens and of our sea by the force of gravity, but I have not yet assigned a cause to gravity. Indeed, this force arises from some cause that penetrates as far as the centers of the sun and the planets . . . I have not as yet been able to deduce from phenomena the reason for these properties of gravity, and I do not feign hypothesis. For whatever is not deduced from phenomena must be called a hypothesis; and hypothesis, whether metaphysical or physical, or based on occult qualities, or mechanical, have no place in experimental philosophy. In this experimental philosophy, propositions are deduced from the phenomena and are made general by induction . . . And *it is enough that gravity really exists and acts according to the laws that we have set forth* and is sufficient to explain all the motions of the heavenly bodies and of our sea' (Newton, 1999 [1687], p. 943, emphasis added)

Newton had put forward a theory of gravity that explained attraction but did not consider a causal mechanism affecting this force. Finding a cause to gravity was, ironically for him who claimed *hypothesis non fingo*, Newton's most fertile source for them. But his realism becomes explicit when he asserts that '*it is enough that gravity really exists'*. Behind the appearances of this theologically charged addendum, there is an important methodological implication. It not only expands on the nature of Newton's experimental philosophy, but it also suggests that existence is what really matters. Truth is not necessarily manifest.[1] This judgment applies equally to God as to the nature of gravity. Causes unknown not necessarily deny their existence. On the contrary, they simply 'are' and we must strive to uncover them instead of supposing a wrong cause like Descartes's 'theory of vortices'.

Leibniz, the most capable representative of mechanical philosophy, argued that a contact mechanism was needed to explain gravity. This represented a serious rebuttal of Newton's idea that gravity 'simply exists'. It also entailed a metaphysical question on God's role. If Leibniz exposes a notion of a pre-established harmony stressing God's omniscience, Newton's God intervened in nature initiating an enlightened tradition in which human beings could be capable of finding out reasons for God's actions. Not surprisingly Leibniz, in a letter dated 1715, ironically complained to Samuel Clarke that '[a]ccording to their Doctrine [Newtonians], God Almighty wants to *wind up* his Watch from Time to Time' (Clarke, 1717, p. 5).[2] At a general level, on the one hand Leibnizians claimed that Newton did not provide a clear mechanical basis, so his system simply represented a return to the Aristotelian-scholastic notion of 'occult qualities'. On the other hand, Newtonians denied that the world could be simply treated as a complete and self-sufficient machine. In sum,

[1] In Montes (2003, pp. 741–3), I pointed out some similarities between Newton's actual method and critical realism. A year after that piece was submitted *The Cambridge Companion to Newton* was published. In it, the editor George E. Smith, in his essay 'The Methodology of Principia' analyses Newton's four rules and refers to his second rule writing that '*same effect, same cause* – authorizes inferences that Charles Saunders Peirce would have labeled abductive in contrast to inductive' (Smith, 2002, pp. 160–1, emphasis in original). Considering that critical realism has defended a retroductive model of inference that very much resembles Peirce's abductive inference (see Lawson, 1997, p. 294, note 14), it is encouraging to read an eminent scholar like George E. Smith making the same link.

[2] Samuel Clarke published Leibniz's letters and his replies a year after Leibniz's death, in 1717, as *A Collection of Papers which passed between the learned late Mr. Leibniz and Dr. Clarke, in the years 1715 and 1716. Relating to the Principles of Natural Philosophy and Religion*. Clarke represented the position of his friend and master Newton.

Principia's mechanical laws do not necessarily explain the origin and sustained existence of natural phenomena.

In the first edition of *Principia*'s, Book 3 'The System of the World' begins with nine hypotheses that Newton turned into 'rules' and 'phenomenon' in the second and third editions.[1] The first four 'rules for the study of natural philosophy' have become emblematic in understanding Newton's 'experimental philosophy'. The controversial rule 4, added for *Principia*'s third edition, states:

> In experimental philosophy, propositions gathered from phenomena by induction should be considered either exactly or very nearly true notwithstanding any contrary hypothesis, until yet other phenomena make such propositions either more exact or liable to exceptions. (Newton, 1999 [1687], p. 796)

This statement is very different from the commonly received view of Newton's legacy. Instead of an emphasis on the apodictic character of a theory, or a concern on its permanent explanatory powers, Newton simply leaves theories as open-ended. The widespread reception of Newtonianism among economists, linking, in particular, Smith's Newtonianism to general economic equilibrium theory, must be put to rest regarding the content of this rule. An axiomatic-deductive model of science is neither Newton's, nor Smith's inheritance. Although I have treated this issue in Montes (2003), recently Schliesser (2005A, 2005B) has given additional and substantial evidence for interpreting Smith's Newtonian theory of science as a research tool for a potentially open-ended process of successive approximation.[2] Newton accepts that the progress of natural philosophy is open-ended, arguing for partial truth until proven otherwise, and rebutting, as it will be argued below, mathematical event regularities as the hallmark of scientific progress. Laws, for Newton, including the 'universal' law of gravity, can be open to refinement as part of this successive approximation process. Adam Smith, as will be shown in Section 4 of this essay, understood this crucial aspect of Newton's methodology very well.[3]

In his *Opticks*, Newton feels more at ease writing the successive 31 queries.[4] Obviously the nature of these investigations gave him more freedom to express his speculations. It is not a coincidence that this work was first published in English. *Opticks* was more popular, and certainly more accessible to the general public.[5] The corpuscular theory of light entailed difficult questions, especially about the inner nature of matter. But Newton did not hesitate to finish his work 'proposing only some queries, in order to a farther search to be made by others' (Newton, 1979 [1704], p. 339). These speculative queries might contradict the beginning of his *Opticks*: 'My design in this Book is not to explain the

[1] The second edition contains three rules and four hypotheses. The third edition adds a fourth rule.

[2] In fact, Bernard Cohen, George Smith and Howard Stein are the leading Newtonian scholars to have investigated Newton's commitment to an open-ended process of successive approximation. For example, Smith (2002) refers to rule 4, arguing that '*quam proxime* amounts to an evidential strategy for purposes of ongoing research' (p. 159) and then brilliantly underlines that 'the process of successive approximations issuing from Newton's *Principia* in these fields has yielded evidence of a quality beyond anything his predecessors ever dreamed of' (Smith, 2002, p. 162).

[3] Andrew Skinner (1979, *passim*) had already underlined connections between Smith, Kuhn and Shackle in terms of his philosophy of science, but Schliesser is more precise in his treatment of 'Smith as a realist about Newton's theory'. For excellent analysis of this and other issues see also Smith (2002) and Stein (2002).

[4] The first English edition (1704) contains only 16 queries. The Latin edition *Optice* (1706) added seven new queries (numbered 25–31), and the second English edition, published in 1717, added eight more queries (numbered 17–24).

[5] For example, John Locke could not understand the mathematical proofs in *Principia*. This simple difference between both *ouvres* also entail two 'rather different traditions of doing science' (see Cohen and Smith, 2002, p. 31). However, I would add that methodologically, as it will be implicitly suggested here, there is no difference between later editions of Newton's works.

Properties of Light by Hypothesis, but to propose and prove them by Reason and Experiments' (Newton, 1979 [1704], p. 1).

Many passages in these queries relate to an explanation of God through Newton's experimental philosophy, especially in its relationship to the cause of gravity, in the same tenor of *Principia*'s famous *General Scholium*. But there are some suggestions about Newton's actual methodology. For example, at the end of query 28, Newton states:

> And though every true Step made in this Philosophy brings us immediately to the Knowledge of the first Cause, yet it brings us nearer to it, and on that account is to be highly valued. (Newton, 1979 [1704], p. 370)

This is another reflection of Newton's method of approximation to reality. Not denying truth, he is confident that deviations from actual phenomena actually bolster up the advancement of scientific knowledge.

But we can find an additional important methodological point: 'in Natural Philosophy, the Investigation of difficult Things by the Method of Analysis, ought ever precede the Method of Composition' (Newton, 1979 [1704], p. 404). Also remember that in *Principia*'s *General Scholium* Newton refers to the nature of his 'experimental philosophy' in which 'propositions are deduced from the phenomena and are made general by induction' (Newton, 1999 [1687], p. 943). This is a crucial point that has been relatively ignored: analysis precedes and, moreover, has pre-eminence over synthesis (see Montes, 2003). If there are no deviations our conclusions will stand, but if disruptions from phenomena do appear, we should simply enhance the pursuit of scientific truth through reiterative analysis that will successively lead to a new synthesis. Newton follows his argument, in what is perhaps the best passage to explain his actual methodology:

> And if no Exception occur from Phenomena, the Conclusion may be pronounced generally. But if at any time afterwards any Exception shall occur from Experiments, it may then begin to be pronounced with such Exceptions as occur. By this way of Analysis we may proceed . . . in general, from Effects to their Causes, and from particular Causes to more general ones, till the Argument end in the most general. This is the Method of Analysis: And the Synthesis consists in assuming the Causes discover'd and establish'd as Principles, and by them explaining the Phenomena proceeding from them, and proving the Explanations. (Newton, 1979 [1704], pp. 404–5)

This kind of dialectical methodology acknowledges not only a process of successive approximation to reality, but also a prioritisation of the method of resolution (or analysis). The method of resolution allows us to infer causes from phenomena, and the method of composition a (or some) principle(s) from which we can explain other phenomena. Moreover, when he refers to 'any Exception' in the last passage, this also evidences Newton's realism. Although he is cautious about truth, he never denies its existence. But this search is also most likely the source for Newton's late concern with methodology.[1]

[1] In a very suggestive essay, Strong (1952) argued for a sort of 'Newton Problem' (à la *Adam Smith Problem*). It is suggested that initially Newton's *Principia* and *Opticks* were originally delivered without reference to God. In fact, the *General Scholium* was added 26 years after the first edition of *Principia* in 1687, and the queries mentioning God first appeared in the Latin edition *Optice* in 1706 and especially for the Second English edition of 1718. Certainly Newton's need to somehow explain the cause of gravity, the main attack from the Cartesians, might have influenced his reliance on a theological argument, or his need to appeal to God. But given that Newton was a true believer, perhaps Strong's argument can be extended towards Newton's concern with his methodology as an open-ended process of successive approximation. It is undeniable that Newton was well aware of his experimental philosophy, but it is at least curious that his 'mathematical way' acquired significant methodological nuances as he grew older. At least there is a move towards explaining methodological issues.

Newton had the answer for how the world worked, but he didn't know why it worked that way. He could describe gravity but he could not explain its causal powers.

So far I have concentrated simply on *Principia* and *Opticks*, but it must be mentioned that Newton's unpublished papers do present further evidence for the interpretation I have been trying to develop.[1] Just to give one example, in a fragment that was probably intended for *Opticks*, Newton refers to the method of resolution and composition, adding that 'he that expects success must resolve before he compounds. For the explication of Phaenomena are Problems much harder than those in Mathematicks' (McGuire, 1970, p. 185). Scientific progress is not only a matter of achieving mathematical regularity, nor is it a precondition of Newton's method. If his discoveries created a mathematical system of nature, we cannot infer that Newton's natural philosophy encouraged a particular mathematical-positivistic interpretation of his method.[2]

3. On eighteenth-century Newtonianism

In this section I will mainly, and perhaps perfunctorily, concentrate on the British (particularly Scottish) and French reception of Newton. It will be suggested that France and Britain adapted Newtonianism to their scientific agendas. As a caveat, I must underline at the outset that any classification of what Newtonianism really was, or any generalisation on how a particular country inherited Newton's legacy is, to say the least, highly nuanced. However, we can infer what Newtonianism is not. In addition, some tendencies to adapt his legacy in Britain and France, can, I believe, be drawn. Some interesting connections to history of economic thought will emerge.

The reception of Newton's legacy during the eighteenth century was largely multifaceted. To begin with, Schofield (1978) distinguishes Baconian, Leibnizian, Cartesian and Newtonian 'Newtonianisms', although he rightly concludes that 'Newton was not a Newtonian in any one of the many versions which can be identified' (Schofield, 1978, p. 177).[3] Furthermore, Paul Wood has recently argued that 'his writings [Newton's] were read in such radically different ways that it is difficult to identify a unified Newtonian tradition in the moral sciences' (Wood, 2003, p. 802). Eighteenth-century *philosophes* carefully adopted Newton's successful discoveries as a paradigm, but many of them adapted his methodology without care. If it was Newton's intention 'to a farther search to be made by others' (Newton, 1979 [1704], p. 339), the consequences of his intentions were not always really Newtonian.

Bernard Cohen and George Smith raise an important point when they say that following Newton's death, eighteenth-century scientists had the 'difficult task of reconciling Newtonian theory with observation' (2002, p. 7). Also, the spectacular discoveries of

[1] For example, Kuhn underlines that although Newton 'has seemed to support the further assertion that scientific research can and should be confined to the experimental pursuit of mathematical regularity ... Careful examination of Newton's less systematic published writings provides no evidence that Newton imposed upon himself so drastic a restriction upon scientific imagination' (1958, p. 45).

[2] Expanding on this view, see Montes (2003, pp. 725–32). Strong (1951) investigates Newton's 'mathematical way', noting not only that his Method of Fluxions is first and foremost geometric, but also arguing for a 'mathematical experimentalism in which measurements and rules of measure prepare the mechanical principles' (p. 107). Mathematics, for Newton, 'is a tool devised to assist in the solution of physical problems' (Strong, 1951). Elsewhere he defends the thesis of a Newtonian 'mathematical conceptualism' followed by MacLaurin, Pemberton and 'sGravesande, which contrasts with Keill's 'mathematical realism' (Strong, 1957). Moreover, Newton's views on mathematics give pre-eminence to geometry. The way he developed his 'calculus of fluxions' (differential calculus) and his 'method of flowing quantities, or fluents' (integral calculus) reflects the importance he gave to classical geometry before pure mathematics (see especially Guicciardini, 1989, 1999, 2002).

[3] On the varities of Newtonianism see also Guerlac (1977) and Schaffer (1990).

Newton's new 'system of the world' left natural phenomena fertile for giving birth to further analysis and synthesis. The inevitable outcome was a variety and diversity of interpretations of Newton's methods, reflecting a renewed interest in scientific matters after the so-called scientific revolution.[1] But this interest was very different in the context of Britain, with the scientific community under Newton, and France, with its scientific institutions still backing the Cartesian legacy. In Britain, just after Newton took over the Presidency of the Royal Academy in 1703, he was a kind of scientific dictator. But after his death, he became the world's scientific legislator.[2]

There is evidence that Scottish universities were not only prominently Newtonian, but also instrumental in establishing Newtonianism in Britain. From the 1690s onwards, they 'led the way in the institutionalisation of the Newtonian system' (Wood, 2003, p. 810). Christine Shepherd (1982) has done archival research on Newton's rapid acceptance at the Scottish universities from the 1660s up to the early eighteenth century, concluding that Scotland witnessed 'a considerable degree of progress in natural philosophy at the end of the seventeenth century and during the early years of the eighteenth' (p. 83).[3] This fact was no doubt due to the enormous influence of the Gregorys at St Andrews and Edinburgh, who taught almost continuously from 1660s to the 1720s. James Gregory (1638–75) invented the reflecting telescope and corresponded with Newton. His nephew, David Gregory was also an important disciple of Newton and a member of his intimate circle. Both Gregorys were instrumental in forming generations of eximious mathematicians that helped to spread Newton's early reception.[4]

But as Shepherd (1982) and Wood (2003) have shown, many other Scottish intellectuals contributed to the spread of Newtonianism in Britain. It is acknowledged that Glasgow University took longer to accept Newtonianism initially, but as early as 1711 it became part of the Newtonian network with the election of Robert Simson, another important Scottish mathematician, to a chair in mathematics (Wood, 2003, p. 100). This only reflects the Scottish permeability towards Newtonianism. If James Gregory was the inspiring figure, it was David Gregory with his physician friend Archibald Pitcairne (leading exponent of a 'mathematical physick'), together with Colin Maclaurin, who also recognised and spread Newton's achievements.[5] For example, a Scotsman who studied with David Gregory, John Keill (1671–1721), began lecturing on Newton's natural philosophy in Oxford as early as 1699, initiating an experimental course in Newtonian physics.[6] In 1712 he was elected

[1] Although the so-called 'scientific revolution' actually took place in the seventeenth century (see Cohen, 1985, 1994 and Henry, 1997), the eighteenth century has been traditionally considered a dull period in scientific progress. Roy Porter, as editor of *The Cambridge History of Eighteenth-Century Science*, an its contributors, have done a great contribution to restate the scientific achievements of the eighteenth century.

[2] Indeed, it could be argued that Newton's legacy was in the background of scientific development during the eighteenth century: 'Newtonianism set the intellectual boundaries within which much of the activity of eighteenth-century natural philosophy was conducted' (Gascoigne, 2003, p. 289).

[3] Brockliss (2003) states that '[b]y the 1690s his [Newton's] theory of universal gravitation, as well as his work on light and color, was being discussed by professors of philosophy in the Scottish universities' (p. 47).

[4] James Gregory became professor of mathematics in St Andrews in 1668, and then professor in the new mathematics chair at the University of Edinburgh in 1674. David Gregory (1659–1708) succeeded his uncle James Gregory as professor of mathematics at the University of Edinburgh in 1683. In 1692 he was admitted to Balliol College, Oxford, and then, supported by Newton, he was appointed Savilian chair of astronomy at Oxford.

[5] Actually they both inspired Scottish figures like John and James Keill, John Freind, Matthew Stewart, George Cheyne, George Hepburn and William Cockburn.

[6] John Keill, according to his successor Desaguliers, was the first one to teach Newtonian physics 'by experiments in a mathematical manner' (quoted in Guerlac, 1981, p. 118).

Savilian professor of astronomy at Oxford. John Craig, who also studied under David Gregory, was another important Scottish mathematician well acquainted with Newton.

Colin Maclaurin (1698–1746) was an exceptionally gifted Scottish mathematician who early in life, when he was only 15, submitted a sophisticated thesis in which he expounded Newton's law of gravity. He rapidly assimilated Newton's calculus, and 'was arguably the most capable and energetic exponent of Newtonianism working in Scotland, if not in Britain, during the first half of the eighteenth century. He helped not only to consolidate the Newtonian hold on Scottish academe, but also to create public science in the Scottish Enlightenment' (Wood, 2003, p. 102). Maclaurin fully grasped Newton's methodology, and his influence through his *An Account of Sir Isaac Newton's Philosophical Discoveries* was tremendous in Scotland and in England. Adam Smith perhaps was just another savant who benefited from Maclaurin's sophisticated interpretation of Newton.

Other influential and popular accounts of Newton's new system during the first half of the eighteenth century were Henry Pemberton's (1694–1771) *A View of Sir Isaac Newton's Philosophy*, published in 1728, a year after Newton's death, and Voltaire's (1694–1778) *The Elements of Sir Isaac Newton's Philosophy* (1738). But MacLaurin's notable *An Account of Sir Isaac Newton's Philosophical Discoveries*, published in 1748, is perhaps the best account written in the first half of the eighteenth century.[1]

At a general level, with the arrival of the first Hanoverian monarch in 1714, scientific exchange between Britain and the Continent was greatly stimulated. In particular, Willem Jacob 'sGravesande (1688–1742), who held the chair of mathematics and astronomy at Leiden from 1717, arrived to Britain in 1714 as secretary of the Dutch embassy. He became an important transmitter of Newtonian science within Europe. Indeed, 'sGravesande's *Mathematical Elements of Natural Philosophy, Confirm'd by Experiments or, an Introduction to Sir Isaac's Newton Philosophy* (1720), was perhaps the best textbook on Newtonian science during the first half of the eighteenth century. Jean-Théophile Desaguliers (1683–1744), who took over Keill's lecture course at Oxford, translated and published in English 'sGravesande's *Mathematical Elements of Natural Philosophy* in 1721.[2] In 1719, Desaguliers, based on Keill's lectures, had published his *Lectures of Experimental Philosophy*,[3] and in 1734 his popular *A Course of Experimental Philosophy* appeared.

Newton, in an attempt to expand his methodology to other disciplines, in his *Opticks*'s query 31,[4] just in the last paragraph of this book, declared '[a]nd if natural Philosophy and all its Parts, by pursuing this Method, shall at length be perfected, the Bounds of Moral Philosophy will also be enlarged' (Newton, 1979 [1704], p. 405). This was taken seriously by the Scottish savants. Hutcheson, perhaps following Pufendorf's early suggestion that moralists should use the methods of natural philosophers, might also have been following

[1] Initially Maclaurin's contribution was conceived as a companion to a biography of Newton projected by Conduitt, who was married to Newton's niece, Catherine Burton. Once John Conduitt died (1737), Colin Maclaurin continued to work in his project, which was finally published two years after his death (see Strong, 1957, p. 54). Other very popular and influential works were Francesco Algarotti's (1712–1764) *Sir Isaac Newton's Philosophy Explain'd for the Use of the Ladies* (1737), and Bernard de Fontenelle's (1657–1757) popular *The Elogium of Sir Isaac Newton* (1728).

[2] Its success in Great Britain is confirmed by the fact that it went through six editions between 1721 and 1747, and it circulated widely in France, although only in 1746–47 was it published in French. Another important figure in disseminating Newtonianism was William Whiston (1667–1752), Newton's successor as Lucassian professor, who lectured in Cambridge from 1703 until 1710. His *Sir Isaac's Newton's Mathematick Philosophy More Easily Demonstrated* appeared in 1716.

[3] In 1719 he also published *A System of Experimental Philosophy, Prov'd by Mechanicks*.

[4] The last query, numbered 31, was added for its first Latin edition, *Optice*, published in 1706.

Newton's query initiating a tradition of 'moral calculus'.[1] If Hume has been considered as a paradigm of Newton's influence, George Turnbull (1698–1748) was perhaps the first Scottish academic who explicitly invoked Newton for his moral investigations. In his *The Principles of Moral Philosophy* (1740) Turnbull states that 'we must enquire into moral phenomena, in the same manner as we done into physical one', fully reproducing Newton's query 31 in the title page of the first edition. Thomas Reid was another inheritor of this Newtonian tradition, as his explicit references to Newton's 'four rules for the study of natural philosophy' evince. Newton's influence on moral philosophy, mathematics, political economy, physiology and medicine, among other disciplines, is tremendous and complex as his influence pervaded all areas of knowledge.

But one of the more puzzling questions is how Newton's method was understood. Many scholars, notably Paul Wood, have contributed to the clarification of what is 'Newtonianism' within the broader project of the Scottish Enlightenment. In my view, it was Newton's methodological influence, epitomised by his analytic-synthetic method, and his acknowledgement of scientific progress as an open-ended process that contributed to the development of Scottish moral philosophy. With its complexities and different nuances, it is undeniable that 'the Newtonian corpus shaped the pursuit of the human sciences in the Scottish Enlightenment to a far greater extent than is often recognised' (Wood, 2003, p. 107).

The French context was different in terms of Newton's early reception and what came to be known as Newtonianism. Initially it was through Newton's optical work and his reflecting telescope that he first became famous in French scientific circles, but *Principia* was not ignored, simply rebutted. Huygens and Leibniz were competent critics of Newton's law of gravity, and as inheritors of mechanical philosophy, they did their best to explain matter and its interaction as a cause for attraction. If in France it was difficult to accept the notion of a void, the idea of bodies attracting one another without any material cause was generally deemed as preposterous. Indeed, the most entrenched notion in France was the insistence on mechanisms and contact between bodies which clashed with Newton's existence of universal gravitation as a force operating universally and independently of any direct mechanical contact. Descartes had defined matter as an infinitely extended plenum, but Newton formulated his concept of universal gravitation operating in bodies *in vacuo.*

Voltaire's celebrated *Letters Concerning the English Nation* (1733)[2] is a great example, which not only shows Newton's popularity but reflects the context of a great divide between French Cartesianism and Britain's Newtonianism. The new system of natural philosophy had to break through the well established Cartesian regime that was deeply institutionalised in the French scientific community.[3] Just to give one example, the first Newtonian lectures at the University of Paris were not given until the 1740s, as it had remained under the reign of Cartesianism (see Jacob, 1988, p. 201). In fact, '[g]iven the

[1] The first edition of Hutcheson's *An Inquiry into the Original of our Ideas of Beauty and Virtue* (1725) advertised in its first page that the work contained 'an Attempt to introduce a *Mathematical Calculation* in Subjects of *Morality*'. The second edition no longer showed this attempt, and for its fourth edition all mathematical expressions dealing with 'axioms' and 'propositions' were eradicated. However, what might be termed as Hutcheson's mathematical attempt of 'Newtonianian moralism' was by no means followed by the moral philosophy tradition in Scotland.

[2] Especially Letter XIV '*On* Des Cartes *and Sir* Isaac Newton', and to a lesser extent Letter XV '*On Attraction*' and Letter XVI 'On *Sir* Issac Newton's *Opticks*'.

[3] As Guerlac (1981) has argued, it was Malebranche and his followers, especially Maupertius and Clairaut, who disseminated Newton's legacy in France, though it has also been argued that they basically attempted to reconcile Newton with Descartes (see Gascoigne, 2003, p. 299). On Malebranche and his followers great influence on Newton's acceptance in France (see Hankins, 1967).

tenacity with which members of the French *Académie des Sciences* in the first three decades of the eighteenth century attempted to find a mathematical defense of Cartesian vortex ... it is unsurprising that Newton's phenomenological physics was slow to take root in the Continent's colleges and universities' (Brockliss, 2003, p. 61, see also p. 85). But France gave their students an impressive formation on abstract mathematics. Britain, relying on a tradition initiated by Francis Bacon, gave more emphasis to Newton's 'experimental philosophy'. This created two rival traditions of physics: 'one mathematical and one experimental, which have affected the two countries approaches to natural science ever since' (Brockliss, 2003, p. 86).[1] It was only at the end of the eighteenth century that Laplace could finally impose his own 'Newtonian agenda on the French scientific community' (Brockliss, 2003, p. 85).

The idea of a sort of struggle between Cartesian mechanism and Newtonianism, is not original at all,[2] neither can it be defended as a generalised phenomenon. But in my personal view there are grounds to assume that Britain and France stood by the side of their intellectual heroes. In addition, Scotland was not only an early advocate of Newtonianism, but more importantly, the Scottish Enlightenment provided a unique setting for rapidly assimilating and applying original approaches to Newton's ideas. Natural philosophy induced a debate about metaphysics in general (see Stein, 2002), theology and moral philosophy. Disagreement over the nature of gravity and the nature of matter entailed different metaphysical and theological aspects. But this discussion was especially fruitful in Scotland.[3]

There is another cultural difference between France and Scotland at the time of the Newtonian debate, and it relates to the public dissemination of knowledge. In France we have the *salonnières* and in Scotland the coffee shops. If the former were polite meetings mainly hosted by women[4] and attended by aristocratic members and intellectuals, the latter were more open meetings and their locations ranged from polite coffee houses to children's nurseries. In Scotland, this cultural phenomenon has led some commentators to advocate, with historical mindedness, a tradition of 'public science'. For example the Boyle lecturers (Richard Bentley, Samuel Clarke, William Whiston and William Derham) brought Newton's 'system of the world' to the general public, combining his discoveries with a solid theological interpretation that entailed political and ecclesiastical interests.[5]

[1] A representative feature of the British–French divide is that Leibniz's notation for calculus was adopted in France (and the Continent), while in Britain, Newton's notation prevailed during the eighteenth century. The so-called d-dots divide.

[2] On Newton's reception in France, Brunet (1931) states that Cartesians opposed Newtonianism in France, but Guerlac (1981) argues that there was no such an academic division. See also Hall (1975). Certainly Newton's *Opticks* was more popular especially through Malebranche and his followers and Fontenelle's popular *Eloge*, first read to the Royal Academy of Sciences in Paris in 1727.

[3] It is worth noting that Smith refers to 'The opposition which was made in France, and in some other foreign nations, to the prevalence of this system [Newton's]' (*Essays on Philosophical Subjects*, p. 104), but he has an explanation based on the custom of understanding the world as the Cartesians did.

[4] No gender bias. On the contrary: in France women were early promoters of Newton's work. Voltaire's mistress, Madame du Chatelet (1706–49) was close to Maupertius and Clairaut, and also translated Newton's *Principia*, which was published posthumously in 1756. For women and science see Shapin (2003, pp. 184–210).

[5] J. Gascoigne has argued that '[t]hanks to the work of university teachers in both Cambridge and Scotland and to the way in which theologians, following the lead of the Boyle lecturers, incorporated elements of Newtonian natural philosophy into the widely disseminated texts of natural theology Newton's work became closely associated with the established intellectual order in Church and State' (2003, p. 292). Margaret Jacob (1988) presents a vivid account of the socio-political, cultural and religious underpinnings of the modern development of science, and its influence in the industrial revolution. Although Jacob (1988) has persuasively suggested that the political context was fundamental to Newtonianism, Guerrini (1986) shows that there was a wide variety of political and religious viewpoints within Newtonians.

In France, even after Newton's death, his theory of gravity remained still generally unaccepted until the 1730s.[1] If Britain maintained a Baconian emphasis on observation and experiments, the French *philosophes* finally attained the transformation of mechanics in a branch of mathematics. Physical problems, and phenomena in general, were subsumed to mathematics.[2] Moreover, as R. W. Home explains '[a]lthough mechanics became almost entirely mathematical, the mathematics was often remote from any real-world situation' (2003, p. 371). This detachment from reality was neither Newton's intention, nor a clear cut interpretation of his method; it was, perhaps, a consequence of the spectacular nature of his discoveries that influenced a particular axiomatic-deductive reading of his method (see Montes, 2003). Not surprisingly, Malebranche referred to mathematics as 'the foremost and fundamental discipline of all human sciences' (quoted in Guerlac, 1981, p. 56), and many French *philosophes* would follow and exalt this dictum.

Jean le Rond d'Alembert (1717–1783) saw the mathematical analysis of the *Principia* as paradigmatic. For him mathematical deduction took priority over evidence gained from observation. He shared Descartes's ambition of deducing the sciences from first principles.[3] As J. Gascoigne has said, '[i]n France, as the example of D'Alembert suggests, the fascination for the Cartesian project of constructing a system of natural philosophy by a process of rigorous deduction never entirely failed' (2003, p. 302). Joseph Lagrange's *Méchanique analytique* (1788) 'sought to take an essentially Newtonian system of mechanics to a new level of mathematical purity by reducing its subject matter to a set of general formulas from which could be deduced all the equations necessary to solve any given problem' (Gascoigne, 2003). Pierre-Simon Laplace's *Méchanique céleste* (1799–1805) corrected some of Newton's flaws with the use of rigorous mathematics, but maintained the Cartesian ambition 'that all phenomena, both celestial and terrestrial, could be explained by a uniform set of laws' (Gascoigne, 2003).[4] It is this feature of how the French adopted Newton's legacy that completely diverges from his true methodological legacy. Indeed, Cartesian dogmatism was so entrenched in the scientific agenda in France, that even though Newton finally came to be accepted, it was with a characteristically Cartesian flavour.[5] The French emphasis on the axiomatic-deductive nature of scientific enquiry, their emphasis on a mathematical set of assumptions from which all phenomena could be derived, and their search of event regularities, necessarily led them to a positivistic interpretation of Newton's legacy.

On the role of mathematics, the Scottish tradition more fully understood Newton's underlying idea that mathematics is an instrument to describe nature, not a model of reality.[6] Additionally, they generally conceived mathematics, and especially differential calculus, in the geometrical tradition initiated by Newton. The superiority of analytical

[1] The Academy's expedition to Peru and Lapland in 1735 and 1736, corroborating Newton's claim, among others, that the earth was not a perfect sphere, largely contributed to Newton's prestige in France. Margaret Jacob has argued that '[b]y the 1740s, when Newtonian mechanics had captured the educational system in England, in Scotland, and at the major Dutch universities, the French colleges continued to teach Descartes relentlessly' (1988, p. 67).

[2] The French rapidly assimilated the importance of differential calculus. It is noteworthy that Marquis de l'Hospital wrote the first textbook of calculus as early as 1696 (*Analyse des infiniment petits pour l'intelligence des lignes courbes*).

[3] However, his co-editor of the *Encyclopédie*, Denis Diderot, predicted an end to mathematical advances.

[4] How different from Newton's intentions is Laplace's answer to Napoleon, 'I do not need that hypothesis', when asked about the place of God in his cosmological system.

[5] See a 1707 French engraving in Jacob (1988, p. 62) that depicts Descartes as a celebrity, but in late eighteenth-century copies of it, Descartes is substituted by Newton.

[6] Guicciardini (1989) presents an analysis of British mathematics during the eighteenth century.

mathematics and abstract thinking was more pervasive and generally accepted by the French Enlightenment. The Scottish mathematical mind was more phenomenological, deeply influenced by Colin Maclaurin and Robert Simson's geometrical approach (see Olson, 1971). Just remember that for Newton 'the explication of Phaenomena are Problems much harder than those in Mathematicks' (McGuire, 1970, p. 185).

If deduction, rather than the Newtonian analytical-synthetic method, became the hallmark of seventeenth-century Cartesianism, it remained highly influential in France during the eighteenth century. For example, Bernard de Fontenelle's popular *Conversations on the Plurality of Worlds* (1686) exposed Descartes's scientific ideas with his emphasis on a deductive system, but noting that experience was the touchstone of all knowledge.[1] So it is not a coincidence that in his *éloge* of Newton upon his death in 1727, as perpetual secretary of the French Academy from 1699 to 1741, Fontenelle 'revealed how far Newton was still largely viewed through Cartesians spectacles' (Gascoigne, 2003, p. 299). The methodological differences between the French and British traditions of thought are a consequence of, but by no means part of, Newton's legacy. Patriotism, personal rivalries, different scientific agendas, political and cultural idiosyncrasies, among others, contributed towards this divide. If France generally promoted an axiomatic-deductive method, and Britain an inductive methodology based on experiments and observation, Newton defended a process of continuous approximation to reality framed by an analytic-synthetic method.

Smith, as we will see in the next section, might have been influenced by how the Scottish assimilated Newtonianism.

4. On Smith's Newtonianism

Adam Smith expresses his admiration for Newton's legacy acknowledging 'the great work of Sir Isaac Newton'. Certainly Smith's judgment admiring 'the tranquility of that great man' (*The Theory of Moral Sentiments* III.2.2, hereafter referred to as TMS, p. 124) was far from reality. It simply reflected the deified image of the father of the Age of Reason. In his *History of Astronomy* Smith analyses 'the superior genius and sagacity of Sir Isaac Newton' that 'made the most happy, and, we may now say, the greatest and most admirable improvement that was ever made in philosophy' (*Essays on Philosophical Subjects*, hereafter referred to as EPS, p. 98). In addition, reflecting on the relatively widespread practice of extending Newton's methodology to the realm of moral philosophy, Smith is reported to have lectured that 'the Newtonian method is undoubtedly the most Philosophical, and in every science whether of Moralls or Naturall philosophy' (*Lectures on Rethoric and Belles Lettres*, p. 146). Based on all these references, it has often been suggested that Smith attempted to build his system on a Newtonian basis, but the question now is what did Smith make of his knowledge of Newton, and to what extent did he actually understand Newton. On the latter, Mark Blaug argued that Smith 'had a naïve view of what constituted Newton's method' (1992 [1980], p. 53). On the contrary, I will argue that Smith was not only well aware of what Newton actually said, but also that he was a sophisticated interpreter of Newtonianism. Paul Wood, also, too readily classifies Smith with 'the construction of simple, deductive systems in natural philosophy' (2003, p. 812). The picture is more complex, and I will suggest not only that Smith understood Newton better that we thought, but also that many of Smith's insights are quite original. Moreover,

[1] I am indebted to Paul Wood for his comments on Fontenelle's *Conversations*. It was a popular and influential book, which went through five editions in only 4 years.

Smith's reading of Newtonianism might have influenced his realist stance towards ethics and political economy.

The British reaction towards mechanical philosophy was reflected in Smith's writings. He refers to Descartes as 'that ingenious and fanciful philosopher' (EPS, p. 92). In his *History of Astronomy* he clearly understood how Newton's system had surpassed the Cartesian theory of vortices. Smith's essay on astronomy, which was written prior to 1758 (see EPS, p. 103), perhaps while he was studying at Oxford, gives an important background to understanding Smith's Newtonianism. The full title of this essay reads '*The Principles Which Lead and Direct Philosophical Enquiries; Illustrated by the History of Astronomy*', immediately calling our attention to its methodological import. It begins with a psychological account of scientific progress. Yet, the triad of surprise, wonder and admiration are successive steps towards scientific progress. This journey through the psychological stages from 'what is unexpected', through 'what is new and singular' finishing up in 'what is great and beautiful', respectively, forms the ground to understanding the nature of scientific progress as an abstract mental process. Although this underlying abstraction is already present in the classics, it is noteworthy that Smith situates his history within this psychological process. The latter, as an abstraction that gives pre-eminence to the role of imagination, underpins *History of Astronomy*.[1] But this story has a peculiar nature.

Smith defines philosophy as 'the science of the connecting principles of nature' (EPS, p. 45), a definition that carries forward throughout this essay. This idea of 'connecting together' demands something to be connected, implying that this connection exists. Moreover, before proceeding to develop his idea, Smith states:

> Let us endeavour to trace it, form its first origin, up to that summit of perfection to which it is at present supposed to have arrived, and to which, indeed, it has equally been supposed to have arrived in almost all former times . . . Let us examine, therefore, all the different systems of nature . . . [that] have successively been adopted by the learned and ingenious. (EPS, p. 46)

The conditional nature of scientific progress implicit in this passage is embedded within an atmosphere of uncertainty, in an epoch that deemed Newton's discoveries as the scientific climax *per se*, is an aspect of Smith's methodology that has been neglected. According to Smith, Newton discovered that 'he could join together the movements of the Planets by so familiar a principle of connection, which completely removed all the difficulties the imagination had hitherto felt in attending them . . . Having thus shown, that *gravity might be the connecting principle* which joined together the movements of the Planets, he endeavoured next to prove that it really was so' (EPS, p. 98, emphasis added). Smith's use of *might* is not casual. For Smith science is also an open-ended process of successive approximations, which resembles Newton's real methodological legacy.

Smith finishes his account of Newton's discoveries with the following sentence: 'Such is the system of Sir Isaac Newton, *a system whose parts are all more strictly connected together*, than those of any other philosophical hypothesis' (EPS, p. 104, emphasis added). Again, Smith's use of *more* here is not casual. The recurrent idea of connections in nature that exist is sceptically subject to approximation in Smith's account of Newton. The interpretation that 'gravity might be the connecting principle' or the characterisation of Newton's system as 'a system whose parts are all more strictly connected together', simply reflect the fact

[1] However, it must be warned that at the end of his essay on astronomy Smith recourses to his initial intention: 'while we have been endeavouring to represent all philosophical systems as mere inventions of the imagination, to connect together the otherwise disjointed and discordant phaenomena of nature' (*Essays on Philosophical Subjects*, p. 105).

that Newton's system was the most precise that humankind had reached. But it is not the final truth. Newton's scientific success with his connecting principles, prompts Smith to assert that we should take his principles '*as if* they were the real chains which Nature makes use of to bind together her several operations' (EPS, p. 105, emphasis added). Note again, the *as if*'. Indeed, these examples show that Smith understood the open-ended nature of scientific inquiry. This is distinctively Newtonian, as we have shown in Section 3 of this essay. Smith was also well aware that we could approximate successively to reality. This is also quite Newtonian.

The final sentence of Smith's essay is worth reproducing:

> Can we wonder then, that it should have gained the general and complete approbation of mankind, and that it should now be considered, not as an attempt to connect in the imagination the phaenomena of the Heavens, but as the greatest discovery that ever was made by man, the discovery of an immense chain of the most important and sublime truths, all closely connected together, by one capital fact, of the reality of which we have daily experience. (EPS, p. 105)

The reality of gravity, as an observable phenomenon that simply exists, very much reflects the Newtonian reaction against Cartesianism. This feature of scientific reality was not fully shared by Condillac and D'Alembert. For example Condillac argued, in a Cartesian way, that 'a system is the more perfect as the principles are fewer in number', and D'Alembert would maintain that 'the more one reduces the number of principles of a science, the more one gives scope, and since the object of a science is necessarily fixed, the principles applied to that science will be so much more fertile as they are fewer in number' (quoted in Olson, 2003, p. 439). This pursuit of simplicity in terms of numbers was, in general, a French deviation that relied on Newton's successful discoveries. Mechanical philosophy, and Descartes's influence, somehow remained in the background and mathematics superseded reality.[1]

Smith clearly reflects eighteenth-century admiration for Newton's discoveries. The secrets of nature had been unveiled by the simple and familiar principle of gravitation. Pope's intended epitaph for Newton (1730) wonderfully summarises this widespread feeling:

> Nature and nature's laws lay hid in night:
> God said, Let Newton be! And all was light.

But the spectacular nature of Newton's discoveries cannot take us away from the real nature of Newton's methodology. The late Bernard Cohen, an authority on Newtonian studies, once declared that 'Smith was well educated in Newtonian science' (1994, p. 66).[2] I would add that Smith was also quite original in understanding Newton's methodology. Therefore, it is rather difficult to explain why the editor of EPS considers that *History of Astronomy* '[t]hough acceptable to a modern historian in its main lines, it contains so many errors of detail and not a few serious omissions as to be no longer more than a museum specimen of its kind' (EPS, p. 11).

[1] It should be remembered that Smith is very cautious about the use of mathematics, 'the use of those sciences [the higher parts of mathematics], either to the individual or the public, is not very obvious' (*The Theory of Moral Sentiments* IV.2.7, p. 189). Regarding political arithmetic, he famously declared 'I have no great faith in political arithmetic' (*An Inquiry into the Nature and Causes of the Wealth of Nations* IV.v.b.30, p. 534), a belief that is repeated in his correspondence (see *Correspondence of Adam Smith*, 249, p. 288).

[2] When Smith talks about Cassini's observations, he mentions Maclaurin 'who was more capable of judging' (*Essays on Philosophical Subjects*, p. 90), so this is another point to sustain that he was certainly familiar with Maclaurin's famous *An Account of Sir Isaac Newton's Discoveries*.

Smith's *History of Astronomy* is just one expression of how Smith uncovered Newtonianism. But throughout his *An Inquiry into the Nature and Causes of the Wealth of Nations* (hereafter referred to as WN) and his TMS, one can also find the methodological influence of Newton.[1] Mark Blaug argued that the pivotal role of sympathy in TMS, and that of self-interest in the WN, 'must be regarded as deliberate attempts by Smith to apply this Newtonian method first to ethics and then to economics' (1992 [1980], p. 52). Perhaps this and other possible connections will need further reassessment. For Smith the aim of philosophy was to find the 'connecting principles of nature' (EPS, p. 45), or to 'lay open the concealed connections that unites the various appearances of nature' (EPS, p. 51). The latter epitomises Smith's realism as an evolving process of discovery.

The crucial idea that what matters is reality is pervasive in Smith's system. For example, one could argue on this point that 'the propensity to truck, barter, and exchange' for Smith simply exists, regardless of whether it is 'one of those original principles in human nature . . . or whether, as seems more probable, it be the necessary consequence of the faculties of reason and speech' (WN I.ii.1, p. 25)'.[2] The link of Smith's notion of exchange with Newton's gravity, as what really matters is that both simply exist. Of course one reality is psychological, in terms that we accept the propensity to exchange through introspection, and gravity is physical.

It seems not a coincidence that Governor Pownall, in his 1776 Letter reacting to WN, in the very beginning refers to WN as investigating '*analitically* those principles' and then 'by application of these principles to fact, experience, and the institutions of men, you have endeavoured to deduce *synthetically*' (Pownall, 1967 [1776], p. 3, emphasis in the original). This introduction raised by Pownall, recalling the significance of the analytical and synthetic Newtonian method, must certainly have appealed to Adam Smith.

5. Conclusions

Smith's view of the world reflects a clear awareness of the social and political nature of human beings. Although he is remembered as the father of economics, his political economy is founded upon a social system that includes ethics, jurisprudence, history, rhetoric and methodology. We do not live as isolated individuals within a community, but we live as members of our community. The latter implies social interdependence within the framework of sympathetic process. But this process is not necessarily a system of 'individuals pursuing their self-interest in an economic order governed by the laws of supply and demand' (Hetherington, 1983, p. 498). This wrong image has given place to many interpretations that view Smith as an inheritor of Newton. His system of economics would be an image of Newton's system of the world. But as I have argued in this essay, Newton's methodology moves away from a positivistic reading, which is predominant in modern economics. Newton's methodology, and Smith's, as I have attempted to show, entail a notion of an open system, a permanent motivation for seeking truth and an emphasis on the method of resolution above composition. In sum, a distinctively Scottish Enlightenment's approach, that favours phenomena over abstractions.

If Smith can be regarded as the 'father of our science', this paper suggests that this science is very different from the real Newtonianism that this essay has attempted

[1] For more on Smith and Newton on *An Inquiry into the Nature and Causes of the Wealth of Nations* see Montes, 2003 (pp. 733–7).

[2] I am indebted to David Levy for calling my attention to this simple and illustrative example, and to an anonymous referee who argued that Smith is simply suggesting a causal mechanism.

to uncover. If the French adopted and adapted Newton's spectacular discoveries into a different programme that perhaps led to Walras, it was the Scottish who retained a realistic and Newtonian approach to social phenomena. With the benefit of hindsight, the French triumphed.[1] The successful abstraction of mathematics gave rise to another view of the world. Neoclassical economics inherited this view, underpinned by a methodological approach different from that of the real Newton and Smith. This tradition initiated by Newton's spectacular discoveries originally does not lead to an axiomatic-deductive reasoning. But it became our *Zeitgeist*.

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[1] Florian Cajori, in his influential *A History of Mathematics* (1901), declared: 'Mathematical studies among the English and German people had sunk to the lowest ebb [1730–1820]. Among them the direction of original research was ill-chosen. The former adhered with excessive partiality to ancient geometrical methods, the latter produced the combinatorial school, which brought forth nothing of value . . . The labours of Euler, Lagrange, and Laplace lay in higher analysis, and this they developed to a wonderful degree' (Cajori, 1901, p. 246).

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