Come back Marshall, all is forgiven?

Complexity, evolution, mathematics and Marshallian exceptionalism

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ABSTRACT

Marshall was the great synthesiser of neoclassical economics. Yet with his qualified assumption of self-interest, his emphasis on variation in economic evolution, and his cautious attitude to the use of mathematics, Marshall differs fundamentally from other leading neoclassical contemporaries. Metaphors inspire more specific analogies and ontological assumptions, and Marshall used the guiding metaphor of Spencerian evolution. But unfortunately the further development of a Marshallian evolutionary approach was undermined in part by theoretical problems within Spencer's theory. Yet some things can be salvaged from the Marshallian evolutionary vision. They may even be placed in a more viable Darwinian framework.

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Especially after the Great Crash of 2008, many worries about the state of modern economics have surfaced.[1] Some academic observers claim that economics is now overly dominated by mathematical technique rather than real substance: the discipline is creating 'idiot savants' (Krueger 1991) and has become 'sick' (Blaug 1997). But there are differences of opinion on the ultimate roots of the sickness (Hodgson 2011).

Some scholars trace the malady in modern economics to the 'marginal revolution' and rise of neoclassical economics from the 1870s (Milonakis and Fine 2009, Fine and Milonakis 2009). In such accounts, Alfred Marshall is lumped together with William Stanley Jevons, Carl Menger, Léon Walras and others. Marshall – the great synthesiser of neoclassical theory – can even be singled out for special blame for his leading and influential role.

Several historians of economics have persuasively countered the notion of a 'marginal revolution' (Ekelund and Hébert 2002), arguing that instead it was a long, drawn out process starting well before 1870 and continuing at least until 1890. The terms 'marginal revolution' or 'marginalist revolution' are at best misleading, and they did not appear in leading journals until after the Second World War.[2] Others have emphasised the theoretical differences between Jevons, Menger and Walras (Jaffé 1976). While persuasive, these are not the arguments that I wish to pursue here.

If we consider in detail the growth and role of mathematics in economics, from the pioneering work of Augustin Cournot (1838) through the energetic promotions of Francis Edgeworth (1881), Irving Fisher (1892) and many others until the present day, one must be amazed by Marshall's early, isolated and repeated worries about this development. By contrast, if we simply lump all these authors together as 'neoclassicals' or 'marginalists' then we overlook such nuances and differences of great contemporary relevance.

I share the view – promoted by a number of historians and philosophers of science – that metaphors and analogies play a crucial role in scientific development.[3] In his pioneering study of metaphor and analogy in science, Max Black (1962, p. 237) concluded: 'Metaphorical

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[1] The author thanks John Davis, Ben Fine, Richard Nelson, anonymous referees and several others for comments on an earlier draft of this essay. If one is to forgive Marshall, it would not extend to his endorsement of eugenics, for example, which he shared with many contemporaries, including leading economists Irving Fisher and John Maynard Keynes.

[2] The first known appearance of the terms 'marginal revolution' or 'marginalist revolution' is Myint (1946).

[3] See Black (1962), Hesse (1966), Johnson (1981), Way (1991), Mirowski (1994), Maasen et al. (1995), Keller (2002).

thought is a distinctive mode of achieving insight, not to be construed as an ornamental substitute for plain thought.' Metaphors sometimes sustain and feed into meta-theories, which in turn play the role of organising enquiry and directing auxiliary theories, as with Darwin's over-arching principles of evolution in biology, or the notion of optimising agents in mainstream economics. Metaphors can also inspire more specific analogies and ontological assumptions. Arguably, adequate theories of complex systems must unavoidably be multileveled, combining general and particularistic theoretical frames (Hodgson 2001).

My argument is that the differences between Marshall and his other 'neoclassical' contemporaries – including differences on the proper role of mathematics in economics – can be traced in part to fundamentally different organising metaphors, meta-theories, analogies and ontological assumptions. While his neoclassical contemporaries embraced metaphors and formalisms from physics (Mirowski 1989), at this meta-theoretical level Marshall was primarily influenced by the evolutionary theory of Herbert Spencer. The influence of Spencer on Marshall is noted by several Marshallian scholars (Moss 1990, Thomas 1991, Groenewegen 1995, Raffaelli 2003, Cook 2009) but is still often underestimated, partly because the role of metaphor and organising meta-theory are insufficiently appreciated, and partly because few people read or understand Spencer any more.[4] The secondary role of his Spencerian vision in limiting the use of mathematics is also under-explored. Furthermore, once the organising role of a meta-theory is taken on board, the question is raised of what could replace the now-obsolete role of Spencerian evolution in the development of a post-Marshallian economic theory.

This essay is organised as follows. The first section considers the appropriation of metaphors and the enthusiasm for mathematics by early neoclassical writers. The second section contrasts Marshall's much more cautious attitude to the deployment of mathematics in economics. The third section outlines Spencer's thought. The fourth section considers the influence of Spencer on Marshall, and stresses the role of Spencerian meta-theory in guiding Marshall's thought, including his attitude to mathematics. The fifth section draws conclusions, some of which concern the agenda for economics today.

1. Mathematics and physics in early neoclassical economics

Cournot (1838) laid down some of the foundations of the marginalist or neoclassical approach in economic theory. He introduced the notions of function and probability into economic analysis and he was the first to express and illustrate supply and demand curves as functions of price. Irving Fisher (1898, p. 119) noted with regret that Cournot's work was 'passed over in silence, if not contempt'.

The rise of the concept of marginal utility signalled a further opportunity for much greater use of mathematics in general and calculus in particular. Although it was not directly measurable, utility seemed an ideal candidate for uni-dimensional quantification.[5] Albeit with contrasting modes of application, this idea is manifest in the seminal marginalist treatises of

[4] Spencer's output is voluminous. But much can be gained by reading Spencer (1890). The differences between Spencer's and Darwin's theories of evolution must be clearly understood (Hodgson 1993b, 2004a).

[5] See Fisher (1892). Problems within this vision were revealed later, regarding interpersonal comparisons of utility and the adoption by some of ordinal rather than cardinal measures.

Jevons (1871), Menger (1871) and Walras (1874). But their approaches are quite different (Jaffé 1976). Menger was the founder of the Austrian school and they often regarded mathematical models as of limited use.

In contrast, for Jevons (1871, pp. 50, 52, 70), economics 'must be pervaded by … the tracing out of the mechanics of self-interest and utility.' He believed that 'all economic writers must be mathematical so far as they are scientific at all.' In part he justified this stance on the grounds that economics 'deals in quantities', particularly in the form of prices.[6] Jevons forgot that much of mathematics is not about quantities. His complementary presumption of utility as the sole goal of human behaviour also prompted a utilitarian analysis that eclipsed other psychological notions and any lingering Smithian 'moral sentiments'.

Francis Edgeworth pioneered a similar line, embracing both Benthamism and mathematics. Defending the idea that individuals maximize their own utility or pleasure, in his *Mathematical Psychics* Edgeworth (1881, p. 15) argued that '*the conception of Man as a pleasure machine* may justify and facilitate the employment of mechanical terms and Mathematical reasoning in social science.'

Further evidence for this connection comes from the work of the American neoclassical economist Irving Fisher. Originally trained as a mathematical physicist, Fisher was one of the earliest and most forceful evangelists for mathematics in economics. Fisher (1892, p. 85) drew up a table of 'mechanical analogies' where a 'particle' in mechanics 'corresponds to' an 'individual' in economics, 'Space' 'corresponds to' 'Commodity', 'Force' to 'Marginal utility or disutility', 'Work' to 'Disutility' and 'Energy' to 'Utility'. Vilfredo Pareto (1897, p. 490) justified the appeal to mechanics in similar terms:

> Rational mechanics gives us a first approximation to the theory of the equilibrium and of the movements of bodies. ... Pure economics has no better way of expressing the concrete economic phenomenon than rational mechanics has for representing the concrete mechanical one. It is at this point that there is a place for mathematics. ... It therefore appears quite legitimate to appeal also to mathematics for assistance in the solution of the economic problem.

The mention by Jevons, Edgeworth, Fisher and Pareto of 'mechanics' was no accidental turn of phrase. As with Walras (1874), the search for usable mathematical techniques had quickly gravitated towards physics. As Philip Mirowski (1989) demonstrates, a particular kind of late nineteenth-century physics (known as energetics) provided specific formalisms (especially those involving calculus) that guided the general approach to modelling. This approach enshrined a preoccupation with equilibria and elevated the supreme goal of prediction. Inspired by these metaphors, equipped with some basic mechanical analogies, brimming with admiration for the powers of mathematical technique, and driven by expectations of greater forecasting ability, a number of leading neoclassical economists launched their campaign for formalism and precision into the twentieth century.

The persistence of what Mirowski (1989) describes as 'physics envy' among economists has remained a major impulse to extend the scope of mathematics in their subject. But much theory in the natural sciences is not articulated mathematically. Furthermore, when some

[6] Mirowski (2012) points to the severe difficulties in this and other presumptions of an underlying quantitative ontology. Prices depend on suppositions of invariance that are contingent rather than historically universal. The idea of using the presumed quantitative nature of the object of investigation as justification for the prevalent use of mathematics is thus undermined.

physicists have cast their eye on economics they have complained about the unfalsifiability or lack of empirical grounding for its assumptions (e.g. Chatterjee and Chakrabati 2007, pp. 250 ff.).

2. Marshall and mathematics

But while the neoclassical approach promoted a great deal of mathematical enterprise, the role of mathematics in economics long remained a matter of debate, even within the neoclassical camp. The key witness here is Marshall.

In methodological terms, Marshall tried to steer a middle course between *a priorism* and empiricism. In multiple editions of his *Principles*, Marshall (1920, p. 22) quoted and endorsed Gustav Schmoller's statement that: 'Induction and deduction are both needed for scientific thought as the left foot and the right foot are both needed for walking.'[7]

His *Principles* contain much empirical material. His *Industry and Trade* (Marshall 1919) is empirically an even richer account. Generally he combined both theory and fact, arguing that 'facts by themselves are silent' (Marshall 1885, p. 166) but also insisting that theory must face the facts. He was highly sceptical of naïve empiricism, on the one hand, and of excessive formalism, on the other. He saw economic theory as an essential precondition of empirical enquiry, rather than something that emerged automatically from the gathering of data. But he also saw limits to highly general 'pure theory' of the type found in the works of Ricardo and Jevons. Instead, theory had to be related to empirical material. Hence on 12 October 1899 Marshall wrote to William A. S. Hewins, the first Director of the London School of Economics, concerning the economics curriculum at the School:

> The fact is I am the dull mean man, who holds Economics to be an organic whole, and has little respect for pure theory (otherwise than as a branch of mathematics or the science of numbers), as for that crude collection and interpretation of facts without the aid of high analysis which sometimes claims to be part of economic history. (Whitaker, 1996, vol. 2, p. 256)

Marshall again wrote to Hewins on 29 May 1900:

> Much of 'pure theory' seems to me to be elegant toying: I habitually describe my own pure theory of international trade as a 'toy'. I understand economic science to be the application of powerful analytical methods to unravelling the actions of economic and social causes, to assigning each its part, to tracing mutual interactions and modifications; and above all to laying bare the hidden *causas causantes*. (Whitaker, 1996, vol. 2, p. 280)

Marshall thus emphasised the goal for the economist of understanding underlying causes. Marshall wrote to Francis Edgeworth on 28 August 1902. Again he stressed that the role of theory was both essential and limited:

> In my view 'Theory' is essential. … But I conceive no more calamitous notion than that abstract, or general, or 'theoretical' economics was economics 'proper.' It seems to me an essential but a very small part of economics proper: and by itself sometimes even – well, not a very good occupation of time. (Whitaker, 1996, vol. 2, p. 393)

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[7] Schmoller was a leading member of the German historical school. Hodgson (2001, 2005a, 2005b) argues that the idea that Marshall was a generally hostile to the historical school is a myth.

For Marshall, mathematical tools were of great use in the task of constructing and developing a theory, but they were useful primarily as means to clarify and render consistent the argument. Mathematics was not theory as such. Hence on 27 February 1906 Marshall gave the following advice concerning the use of mathematics a letter to Arthur Bowley:

> (1) Use mathematics as shorthand language, rather than as an engine of inquiry. (2) Keep to them till you have done. (3) Translate into English. (4) Then illustrate by examples that are important in real life (5) Burn the mathematics. (6) If you can't succeed in 4, burn 3. This I do often. (Whitaker 1996, vol. 3, p. 130).

Cambridge colleague and former student Arthur Pigou (1925, p. 84) reminisced about Marshall:

> Though a skilled mathematician, he used mathematics sparingly. He saw that excessive reliance on this instrument might lead us astray in pursuit of intellectual toys, imaginary problems not conforming to the conditions of real life: and further, might distort our sense of proportion by causing us to neglect factors that could not easily be worked up in the mathematical machine.

These sentiments are radically different from those that prevail in economics today.[8] Marshall's attitude to mathematics in the years around 1900 serves as a benchmark for much of the discipline at that time, alongside the strong and growing mathematical enthusiasm of a minority of academic economists. But by the end of the twentieth century, mathematics had indeed become the principal 'engine of enquiry' driving the discipline, rather than a subservient tool of discursive theoretical development. Many published models may be accused of neglecting 'factors that could not easily be worked up in the mathematical machine'.

Marshall's reasons for his mathematical caution are not further elaborated by Pigou, but we may take the cue from the former student that his teacher emphasised the gap between mathematical models and 'the conditions of real life' and was concerned a relatively excessive concern with technical formalism may cause us 'to neglect factors that could not easily be worked up in the mathematical machine.' It is possible that Marshall developed this cautious position towards formalisation in Cambridge in the 1860s when he concentrated on the study of mathematics and philosophy. But other factors also came into play. When he turned to economics in the 1870s he developed a conception of economic life emphasising diversity, complexity and evolution to a much greater degree than other neoclassical contemporaries. He saw the mathematics of his era as inadequate in the face of complex and varied reality, and warned of the danger of (relatively simplified) formulae being the 'engine of enquiry', rather than the real kaleidic world.

Marshall's vision of a varied, complex and evolving world was partly inspired by the then-influential discourse of Spencerian evolution. The complex and evolutionary character of economic systems caused him to invocate Spencerian biology (Moss 1990, Thomas 1991, Hodgson 1993a, 1993b, Raffaelli 2003, Cook 2009). His adoption of this meta-theory, rather

[8] Brems (1975) briefly criticizes Marshall's stance, arguing that mathematics is indispensable and should be used as a dominant engine of enquiry. But the former does not imply the latter. Marshall's cautious attitude to the role of mathematics found later expression in the work of his Cambridge student John Maynard Keynes (e.g. 1936, p. 298). Weintraub (2002) argues that Marshall's and Keynes's views became rapidly unrepresentative, even within Cambridge.

than one drawn directly from mechanics or physics, partially accounts for his much more cautious attitude to the use of mathematics in the development of economic theory.

3. Spencer, complexity and evolution

In the second half of the nineteenth century, Charles Darwin was rivalled in standing by Herbert Spencer (Bowler 1983, 1988). Trained in physics and mathematics, and a brilliant polymath and synthesiser, Spencer wrote books on biology and extended evolutionary ideas to ethics and social science. Spencer commenced his prodigious output in the 1840s and his works reached a high peak of popularity in the period from about 1860 to 1890. He became a towering and widely-applauded figure in the world of learning. He was particularly popular in the USA, where from 1860 to 1903 over 386,000 of his books were sold (Hofstadter 1959, p. 34). The writings of Marshall cannot be fully understood without an appreciation of Spencer's thought and influence.[9]

It was Spencer, not Darwin, who popularized the term 'evolution'. Darwin did not introduce the word until the sixth edition of the *Origin of Species*, and then only sparingly. On the whole, Darwin preferred phrases like 'descent with modification' to 'evolution'. Furthermore, it was Spencer, not Darwin, who invented the slogan 'survival of the fittest'. It was not until 1866, after the first edition of the *Origin of Species* had appeared that Darwin was persuaded by his friend Alfred Russel Wallace to use Spencer's 'survival of the fittest' phrase in later editions of that work (Waters 1986, pp. 207-8).

Both Spencer and Darwin (1859) adopted the Lamarckian notion of the inheritance of acquired characters. Darwin allowed for this possibility partly because he was unaware of the mechanisms of inheritance, and he also worried whether natural selection was sufficient to account for the presumed pace of evolutionary change. By contrast, Spencer placed Lamarckian principles at the centre of his theory. This meant not only the adoption of the idea of the inheritance of acquired characters, but also Jean Baptiste de Lamarck's ([1809] 1984) law of increasing complexity in evolution.

Lamarck and Spencer argued that environmental circumstances lead to the differential use and disuse of organs (Burkhardt 1977). High levels of use in an environment encourage the strengthening and development of the organ, while low levels lead to deterioration and eventual disappearance. In addition, characters which are thus developed by use can be inherited by offspring. This leads to greater diversity, which becomes inherited. Evolution in the Lamarck-Spencer account is thus a process of increasing diversity and complexity.

While both Spencer and Darwin saw diversity and variety as part of evolution, these concepts played different roles in their theories. For Darwin (1859), diversity was the prior and essential fuel for the process of natural selection. For him 'variation was present first, and the ordering activity of the environment ("natural selection") followed afterwards' (Mayr 1982, p. 354). Darwin argued that change resulted from a combination of innate variation, environmental adaptation and environmental selection. Although Spencer too saw selection at

[9] Although Spencer is widely described today as a leading advocate of 'social Darwinism', no-one ever described him in such terms until the 1930s. Spencer was an anti-militarist and anti-imperialist. The early (and extremely rare) uses of the term 'social Darwinism' were applied most often to militarists, nationalists and imperialists, and less so to pro-market individualists (Hodgson 2004b, 2006). See also Bannister (1979).

work, for him diversity was more significant as the teleological result of the evolutionary process, rather than its essential starting point.

Spencer (1888 p. 22) defined evolution as ‘a change from an indefinite, incoherent homogeneity, to a definite, coherent heterogeneity through continuous differentiations.’ For him, evolution was a law of the universe, necessarily involving progress. This teleological definition of evolution portends a universal directional movement from one state (homogeneity) to another (heterogeneity). Evolution meant increasing diversity and complexity. More complex forms were generally regarded as fitter and more adaptable.

Spencer’s teleological principles recur in his writings. The first, the ‘change from the homogeneous to the heterogeneous, is displayed equally in the progress of civilization as a whole, and in the progress of every tribe or nation; and is still going on with increasing rapidity’ (Spencer 1890, pp. 342-3). The second concerned a simultaneous tendency towards integration: ‘In every more or less separate part of every aggregate, integration has been, or is, in progress’ (Spencer 1890, p. 307).

With his teleological belief in progress, Spencer (1855, p. 492) proposed that ‘life attains more and more perfect forms’, and that humans were no exception to this rule. Spencer (1851, p. 65) wrote: ‘Progress, therefore, is not an accident, it is a part of nature; all of a piece with the development of the embryo or the unfolding of a flower.’ For him, the evolutionary process was seen as a beneficent journey from the lower to the higher form of organisation or life, and from the inferior to the superior.

Furthermore, he saw evolution as leading to equilibrium and greater harmony, a process he described as ‘equilibriation’. Spencer (1890, p. 524) wrote: ‘the changes which evolution presents cannot end until equilibrium is reached, and that equilibrium must at last be reached’. Spencer (1890, p. 525) thus wrote of ‘a gradual advance towards harmony between man’s mental nature and the conditions of his existence.’ His conception of heterogeneity involves integration and excludes antagonism and strife. While for Malthus, Marx and Darwin, antagonism could be creative, for Spencer it led to destruction.

Darwin upheld no such teleological laws. Instead he focused on detailed causal processes at the micro level. Furthermore, unlike Spencer, Darwin wrote in a letter of 1859 of ‘the theory of Natural Selection, which implies no necessary tendency to progression’ (F. Darwin, 1887, vol. 2, p. 210). Darwin (1871, vol. 1, pp. 166-77) also opined: ‘we are apt to look at progress as the normal rule in human society; but history refutes this. … We must remember that progress is no invariable rule.’

Ideas remarkably similar to Spencer’s have frequently recurred well into the twentieth century, and often without reference to their precursors. The twentieth century has seen the ‘unknowing rediscovery of Spencer’ as Jonathan Turner (1985, pp. 7-8) puts it. For example, Spencer can be regarded as one of the forerunners of general systems theory (Turner 1985). There are also close parallels between Spencer’s ideas and the work of Ilya Prigogine and his associates, with their emphasis on ‘increasing complexity’ and the move from the undifferentiated to the differentiated state in evolving systems (Corning 1983, pp. 73-5).

Unlike Spencer’s system, Darwin’s theory lacked general ‘laws’ of evolution to charm his Victorian audience. The hidden power of Darwin’s theory was its reliance on detailed causal explanation rather than ultimately mystical teleological principles. As Claes Andersson (2008, p. 232) puts it: ‘the extraordinary explanatory force of Darwinism is due to its ability to explain purpose without assuming purpose *a priori*.’

Spencer could not explain the causal powers behind his evolutionary laws. As Robert M. Young (1969, p. 135) argued: 'The main feature of Spencer's explanation was not population pressure but progress itself.' His laws lacked justification. He was thus forced to fall back on to the mystical notion of a universal and unknowable motive force, an 'inaccessible Ultimate Cause' (Wiltshire 1978, p. 207), working generally in the direction of 'progress'.

Spencer's evolutionary theory evoked aspects of the physics of his time, including the law of the conservation of energy (Capek 1961, p. 102, La Vergata 1995). Like neoclassical economists he was also influenced by energetics. Spencer shifted biology away from the population thinking established by Darwin, translating it back 'into the language of physics' (Bannister 1979, p. 19). Charles Sanders Peirce (1923, pp. 162-3; 1935, pp. 15-16) saw a profound inconsistency in Spencer's ideas in his flawed attempt to combine the principle of the conservation of energy with a notion of evolution.

This created an inner tension in Spencer's work. On the one hand, he emphasised evolution and complexity, and prefigured much modern thinking in this area. On the other hand he embraced mechanical metaphors and concepts such as equilibrium that were being enthusiastically adopted by mainstream neoclassical economists. He faced both ways. A very similar dilemma is found in the works of Marshall, who keenly adopted both the mechanistic and variety-generating features of Spencer's system.

4. Marshall and Spencer

Marshall saw the limitations of mechanical reasoning, and turned to biology in his search for inspiration and metaphor. However, the science was young and the mechanisms of evolution were not fully understood. At the time, many biologists questioned the Darwinian approach. There was an alternative and bolder synthesis on offer. For Marshall, as for many of his contemporaries, 'the writings of Herbert Spencer were even more significant than those of Darwin' (Thomas 1991, p. 3). While Darwin was widely applauded, the details of his evolutionary theory were under-appreciated (Bowler 1983, 1988). Laurence Moss (1990) makes a strong but supportable claim that Marshall, like so many others, did not take on board key features of Darwin's theory. His energies were directed more towards Spencer, whose writings remained enormously influential until the 1890s. After Spencer died in 1903, Marshall recollected the great influence of the evolutionist in a glowing tribute in the *Daily Chronicle.* He recollected how a saying of Spencer

> sent the blood rushing through the veins of those who a generation ago looked eagerly for each volume of his as it issued from the press. There is probably no one who gave as strong a stimulus to the thoughts of the younger Cambridge graduates thirty or forty years ago as he. He opened a new world of promise (Marshall 1904, in Pigou 1925, p. 507).

Keynes (1924, p. 13) quoted Mary Marshall's account of how her husband would read volumes of Spencer on their walking holidays in the Alps. Marshall added extensive marginal annotations to successive volumes of Spencer's works (Laurent 2000). In the Preface to the first edition of the *Principles* Marshall ([1890] 1920, p. 6) singled out the writings of Spencer and Hegel above all others, because they had 'affected more than any other the substance of the views expressed in the present book.'

Yet the influence of Spencer over Marshall is often underestimated. To date, discussions of Marshall's use of biology in general and Spencerian evolutionism in particular are rare in the literature.[10] A search in JSTOR of articles in journals in economics mentioning 'Alfred Marshall' found that only 2.6% of them also mentioned 'Herbert Spencer'.[11] When articles published on or before 1930 were considered using the same criteria the frequency was found to be 6.2%. The frequency since 1930 was 2.2%. Appreciation of the Marshall-Spencer connection seems to have declined rather than improved.

Much of Marshall's *Principles* concerns equilibrium and economic statics. He planned a second volume to deal more fully with dynamics and the elusive element of time (Moss 1990, Whitaker 1990). This companion work was to address irreversible changes and organic development, drawing its inspiration more from biology than from physics. Some of these dynamic issues are addressed in the *Principles*, but they remain underdeveloped. Although the *Principles* are peppered lightly with biological metaphors, much of the analysis is mechanical, addressing equilibrium outcomes, as Marshall himself admitted.

At the same time Marshall was aware of the tension between an equilibrium framework and one involving evolution and increasing variety and complexity. This is apparent, for example, in his treatment of increasing returns. It became clear to him that a movement up or down the long-run supply curve would in reality be irreversible, unlike a standard mechanical model. Marshall's intellectual honesty and eye on reality was such that he did not assume away problems of this kind. He became ever-more convinced that increasing returns was a major feature of contemporary capitalism. He was nagged by the problems of increasing returns and time irreversibility for the remainder of his life.[12]

Another tension is present in his treatment of the 'representative firm'. Although he associates this notion with 'organic development', it is essentially a theoretical device to deal with variety by entrapping it, rather than by encompassing diversity within a population-based theory of dynamic competition and change. This largely heuristic concept deals with the varied population of firms by identifying a single set of distinct characteristics which are deemed to represent the heterogeneous population, i.e. the industry as a whole. It is not a single firm, or even a typical firm; it is an imaginary firm which exhibits, in microcosm, the 'representative' features of the entire industry. Perceptions of conflict and diversity within that domain are thus diminished by this concept.[13]

To adopt the terms of Ernst Mayr (1982), the conceptualization of the representative firm in Marshall's work is more an example of Platonic 'typological essentialism' than Darwinian 'population thinking', the latter also having implications for evolutionary analysis in the social sciences (Sober 1980, Metcalfe 1988). In 'typological' thinking species are regarded as identifiable in terms of a few distinct characteristics which represent their essence. Accordingly, all variations around the ideal type are regarded as accidental aberrations.

[10] Exceptions include Reisman (1987), Moss (1990), Niman (1991), Groenewegen (1995), Raffaelli (2003) and Cook (2009).

[11] See www.jstor.org. The search was performed on 18 March 2012.

[12] Concerns about increasing returns are divulged in Appendix H of the *Principles*. For discussions of Marshall's treatment of time and increasing returns see Sraffa (1926), Schumpeter (1954, p. 995), Shackle (1972, pp. 244, 286-96), Loasby (1978), Levine (1980), Currie and Steedman (1990, ch. 2), Thomas (1991), Buchanan and Yoon (1999).

[13] For discussions of the concepts of representative firm and representative agent see Thomas (1991), Kirman (1992), Hartley (1996, 1997) and Schohl (1999).

By contrast, in population thinking, species are described in terms of a distribution of characteristics. Variety and diversity are all-important: 'There is no "typical" individual' (Mayr 1982, p. 46). 'The heart of population thinking', Elliott Sober (1985, p. 880) writes, 'consists in the idea that theories may be stated relating the interactions of population properties and magnitudes.' It is precisely these population and relational properties that the concept of the representative firm ignores.

The 'representative firm' is a reductive method of obtaining a long-period equilibrium for the industry as a whole. But as Thomas (1991, p. 7) remarks: 'If the "representative firm" is a biological concept, is it not strange that two-thirds of the references to it in the *Principles* are in Book 5 which is devoted to mechanical equilibrium analysis?'

But Marshall did not reduce the 'representative firm' to a uniform entity across an industry, and make it represent real firms taken severally. His Spencerian emphasis on the evolution of heterogeneity prohibited this. That change of meaning was accomplished later, by Arthur Pigou, Edward Chamberlin, Joan Robinson and others (Moss 1984, Foss 1991). Marshall's concept applies to the whole industry, rather than a single firm. As a concept it looks forward toward evolutionary economics, and back toward the mechanistic world of equilibrium theory. But a mechanistic vision prevailed, even in Marshall's own work and especially in the hands of later interpreters.

It is not argued that Marshall derived his concept of the representative firm from Spencer. Instead, the concept can be accommodated in a Spencerian framework, but not by Darwinian population thinking. Hence the relatively greater influence of Spencer is manifest in this indirect manner.

The difference between Spencer and Darwin is crucial. Spencer started from homogeneity and saw variation coming later. By contrast, Darwin saw variety as the evolutionary fuel upon which natural selection would operate. Darwinian population thinking rules out the idea of a single representative entity among a population. The greater influence of Spencer allowed Marshall to focus on the representative firm around which other firms are clustered, while acknowledging that variety was important and real. But this drew him back to equilibrium rather than forward to evolution.

Chapter 8 of Book 4 of the *Principles* 'reads like a blueprint of a book on economic biology' (Thomas 1991, pp. 8-9). Consider some extracts from this chapter. Marshall saw an analogy between the subdivision of functions and organic differentiation in nature and similar phenomena in industry. Here the influence of Spencer is abundantly clear. For example, Marshall (1920, p. 240) postulates

> a fundamental unity of action between the laws of nature in the physical and in the moral world. This central unity is set forth in the general rule, to which there are not very many exceptions, that the development of the organism, whether social or physical, involves an increasing subdivision of functions between its separate parts on the one hand, and on the other a more intimate connection between them.[14]

[14] Marshall then refers to the German theorists Haeckel and Schäffle, both of whom were also influenced by Spencer and Darwin.

Marshall here evokes Spencer's central idea that evolutionary progress involves a combination of differentiation and integration.[15] He also endorses Spencer's idea of the unity of the natural and the social sciences. Marshall (1920, p. 241) repeats and illustrates the same notion in a subsequent paragraph:

> This increased subdivision of functions, or 'differentiation,' as it is called, manifests itself with regard to industry in such forms as the division of labour, and the development of specialized skill, knowledge and machinery: while 'integration,' that is, a growing intimacy and firmness of the connections between the separate parts of the industrial organism, shows itself in such forms as the increase of security of commercial credit, and of the means and habits of communication by sea and road, by railway and telegraph, by post and printing press.

Marshall, here refers to 'differentiation' and 'integration' as if they were established technical terms. He retained them in the eighth edition of 1920. What is their origin? They are key concepts in Spencer's frequently reiterated account of evolution. For example, Spencer (1890, p. 360) wrote

> Evolution … is a change from a less *coherent* form to a more *coherent* form … The entire mass is integrating, and simultaneously differentiating from other masses; and each member of it is also integrating and simultaneously differentiating from other members. … Evolution is definable as a change from an *incoherent homogeneity* to a *coherent heterogeneity*, accompanying the dissipation of motion and integration of matter.

Marshall was eclectic and influenced by many authors, but he drew more from Spencer than Darwin. In every edition of his *Principles*, and into the era when Spencer was downgraded and almost forgotten, Marshall (1920, p. 243) repeatedly invoked the Lamarck-Spencer thesis of use and disuse:

> Herbert Spencer has insisted with much force on the rule that, if any physical or mental exercise gives pleasure and is therefore frequent, those physical or mental organs which are used in it are likely to grow rapidly.

Marshall saw 'use and disuse' as an engine of variety and evolutionary development. He saw the principal engine of this increasing diversity and complexity as the Lamarck-Spencer notion of 'development through use'.

These Spencerian notions inspired a distinctive social ontology for Marshall's work. Marshall envisioned an economic 'organism' made up of components with different functions. Instead of inert similar particles subject to forces, Marshall (1920, pp. 89, 764) saw individuals as active and divergent developers of their own varied wants and capacities. Purposeful and creative individuals led to divergence and diversity; they were not uniform particles subject to external forces. Although this notion of creative individuality as a source of diversity has multiple sources (Cook 2009), it also ties in with Spencer's Lamarckism.

While such an ontology may be capable of mathematical representation, it did not fit readily into the mathematical formalisms that other neoclassical economists had borrowed

[15] In an otherwise excellent discussion of Marshall, Loasby (1978, p. 6) quotes the very same words as above from the *Principles*, but sees therein a connection with Adam Smith alone, failing to mention Spencer anywhere in his essay. This is just one example of the neglect of Spencer by leading Marshall scholars.

from physics. Marshall (1920, p. 461) warned of the complications and problems of tractability that would emerge from a more complex and evolutionary perspective:

> economic problems are imperfectly presented when they are treated as problems of statical equilibrium, and not of organic growth. For though the statical treatment alone can give us definiteness and precision of thought, and is therefore a necessary introduction to a more philosophic treatment of society as an organism; it is yet only an introduction.

Note Marshall's use of the phrase 'organic growth': Spencer used it several times. Furthermore, Spencer argued in an essay originally published in 1857 that 'organic growth' put limits on precise empirical grounding and made theoretical development more difficult. Spencer (1888, p. 889) wrote: 'Legitimate deduction presupposes adequate data; and in respect to the *special* phenomena of organic growth, structure, and function, adequate data are unattainable, and will probably ever remain so.' Both Spencer and Marshall saw complexity and 'organic growth' as limiting the development of precise, deductive theory.

With his 'evolutionary' and 'organic' ideas, Marshall had unwittingly begun to undermine his static analysis and underlined unfolding diversity, organisation and complexity. These ideas seemed to play on his mind for the remainder of his life. In one place he emphasizes a distinction between complex evolutionary and mechanistic approaches, by reference to qualitative as well as to quantitative change:

> [The] catastrophes of mechanics are caused by changes in the quantity and not in the character of the forces at work: whereas in life their character changes also. 'Progress' or 'evolution,' industrial and social, is not mere increase or decrease. It is organic growth, chastened and confined and occasionally reversed by the decay of innumerable factors, each of which influences and is influenced by those around it; and every such mutual influence varies with the stages which the respective factors have already reached in their growth. In this vital respect all sciences of life are akin to one another, and are unlike physical sciences. And therefore in the later stages of economics, when we are approaching nearly to the conditions of life, biological analogies are to be preferred to the mechanical, other things being equal (Marshall 1898, pp. 42-3).

Marshall again uses the term 'organic growth' and emphasises qualitative change. In a 1902 letter to John Bates Clark, Marshall expressed further disillusionment with static analysis based on competitive equilibrium. Reflecting on the time around 1870 when he was working out his theory of value, he wrote:

> I then believed it was possible to have a coherent though abstract doctrine of economics in which competition was the only dominant force; and I then defined 'normal' as that which the undisturbed play of competition would bring about: and I now regard that position as untenable from an abstract as well as from a practical point of view (Marshall 1961, vol. 2, p. 67).

In the preface to the eighth edition of the *Principles* Marshall (1920, p. xv) argued that: 'The main concern of economics is thus with human beings who are impelled, for good and evil, to change and progress. ... The central idea of economics, even when its Foundations alone are under discussion, must be that of living force and movement.' He upheld the relevance of biological analogies for this project.

When Marshall published his *Principles* in 1890, Spencer's work on evolution was in its heyday. Twenty years later it was widely abandoned (Peel 1971, Hodgson 1993a, 1993b, 2004a). Marshall noted the shifts opinion among biologists, including the persuasive technical and experimental attacks by August Weismann (1889) and others on Lamarckism. Spencer

(1893) came out the worst in a debate with Weismann (1893). But in a letter to Benjamin Kidd of 6 June 1894, Marshall reported having read the Weismann-Spencer controversy but 'without being convinced' by Weismann's arguments. Marshall went on in this letter to declare his enduring adherence to the idea of the Lamarckian inheritance of acquired characters (Whitaker 1996, vol. 2, p. 114).

Marshall repeated his qualified sentence on 'the Mecca of the economist' in every preface to the *Principles* from the fifth edition on. However, as Thomas (1991) and Whitaker (1990) show, he delayed and procrastinated over the planned second volume with its greater emphasis on dynamics. The growing unpopularity of Spencer's evolutionary system after the 1890s made the task much more difficult. As Moss (1990, p. 85) argues, the problem for Marshall was not a commitment to evolutionary biology in general. Instead 'it may have been his stubborn commitment to a particular variant of evolutionary biology (that is, Spencer's version of evolutionary biology) that blinded him'. To complete the second volume and accord with contemporary biological thinking, Marshall would have to find an alternative over-arching evolutionary theory.[16]

Later Marshallians neglected the biological aspects of Marshall's thinking, and abandoned any attempt to recast economics along biological or evolutionary lines. Thus, for instance, Pigou (1922, 1928) turned instead to physics for inspiration, and in his hands the representative firm became the firm in mechanical equilibrium. Equilibrium concepts were developed that were no longer consistent with heterogeneous economic agents (Moss 1984, Foss 1991).

By the time of Marshall's death in 1924, the dialogue between economics and biology had virtually ceased.[17] In an article on Marshall marking the centenary of his birth, Gerald Shove (1942, p. 323) noted 'a return to the mechanical as against the biological approach' in mainstream economics. Despite its Marshallian pedigree, the theory of the firm in the post-war microeconomic textbooks showed little trace of biology (Gee 1983, Newman 1960). Biology was virtually excluded from economics from the late 1920s until the middle of the century, when it began slowly and sporadically to reappear (Hodgson 1999, ch. 5; 2004a).

5. Conclusion: Marshall and the economics of tomorrow

We now bring the threads together and turn to the relevance of the above discussion for modern economics. A key hypothesis is that there is a connection between Marshall's cautious use of mathematics and his Spencerian evolutionism. The notion of ever-increasing variation and increasing complexity in Spencerian evolution poses a challenge to many formal models, particularly those based on metaphors from nineteenth century physics. Marshall acknowledged the diversities among human agents and organisations and their continuous evolution through time. He believed that if they were useful at all, models had to help us understand the real world. And if the real world was one of unceasing flux and ever-

[16] As Whitaker (1990) argues, there were additional reasons why Marshall failed to produce the second volume, including his focus on applied research, his involvement in Parliamentary committees, his perfectionist hesitation, and eventually his declining health.

[17] It lived on for a few more years in the United States, partly through the influence of Veblen. But by the 1930s even most of Veblen's followers had abandoned his biologically-inspired evolutionary research programme (Rutherford 1998, Hodgson 2004a).

increasing diversity, then the simpler models of his time would always be limited in their capacities to address this reality.

But the issue is more complex. Other authors might accept the varied and changing nature of reality but react in a different way, by arguing that this variety and complexity rule out the use of mathematics which abstracts from or limits these features. For example, Tony Lawson (1997) argues that socio-economic reality is generally complex and evolving. The researcher faces the challenges of dealing with open systems within which agents have radical uncertainty about the future. Given this ontology, he claims that mathematics is generally unsuited, because it involves closed systems and excludes uncertainty.

But if this argument were true, it would apply to other sciences dealing with complex and evolving phenomena, particularly biology. Yet biology exhibits several important and successful examples of mathematical analysis. Implicit in Lawson's argument is that mathematical models should sufficiently resemble in key respects to the ontological features that they address. But in biology and elsewhere models involve a high degree of abstraction and number of simplifying assumptions that conflict with reality itself – and there is no reason that they must necessarily fail because of this limitation. Any claim that models always should try to mirror essential features of reality is unwarranted.

Furthermore, Lawson's argument is based on an over-emphasis on the use of models for prediction. As I have argued more fully elsewhere (Hodgson 2006, ch. 7), he belittles the alternative role of models as explanatory heuristics. The primary role of heuristics is not to predict. Their purpose is to identify possible causal mechanisms that form part of a more complex (and inevitably open) system. Heuristics can be useful without necessarily making adequate predictions or matching existing data. Their purpose is to establish a plausible segment of a whole causal story, without necessarily giving an adequate or complete explanation of the phenomena to which they relate. As noted above, Marshall explained that he used mathematics to clarify and check his conceptual reasoning. This deployment of formal methods is a version of heuristic usage.

Consider another possible reaction to the hypothesis in the first paragraph of this section. A neoclassical economist might react to Marshall's observations concerning complexity and evolution and freely admit their presence the real world. The neoclassical economist would then point out that all science necessarily involves abstraction, isolation and simplification. This point would have to be conceded by a Marshallian (or Lawsonian) opponent. Science unavoidably proceeds in such a manner.

But the next neoclassical step would be to use the paradigm and organising metaphor of mechanics to make particular simplifying assumptions. Assumed away would be diversity among individuals and perhaps even their changing preferences. Particles would replace living agents. The focus would be on equilibrium rather than evolution. Increasing returns would be relegated in importance or removed from the models, and so on.

The claim here is that the over-arching metaphors and meta-theories help determine the particular simplifications and abstractions that are chosen in a model. They also help determine a kind of implicit prioritisation, for which assumptions or simplifications are the most temporary of expedients and would be the first to be removed.

Because his meta-theory was largely Spencerian, Marshall felt uneasy with any reduction to mechanics that assumed away the inbuilt generation of variety at the individual level. He often relapsed into equilibrium analysis. But he was always keen to transcend statics and move to dynamics, as that corresponded to the fuller version of his Spencerian vision.

If this argument is correct, then it accounts for Marshall's exceptional qualms concerning the use of mathematics, compared with other neoclassical economists. Their different attitudes to formalism stem from a clear difference of metaphor and meta-theory.

What are the implications of this for the economics of tomorrow? We now know that Spencerian evolutionary theory is flawed and inadequate. Darwinism has been in the ascendant. More than a century ago, Veblen (1900, p. 265) wrote:

> Professor Marshall shows an aspiration to treat economic life as a development; and, at least superficially, much of his work bears the appearance of being a discussion of this kind. ... His insistence on the continuity of development and of the economic structure of communities is a characteristic of the best work along the later line of classical political economy. All this gives an air of evolutionism to the work.

Veblen argued that economics should absorb the full impact of the Darwinian revolution in science. Veblen (1908, pp. 399-400) called for a 'post-Darwinian science' with

> a new distribution of emphasis, whereby the process of causation, the interval of instability and transition between initial cause and definitive effect, has come to take the first place in the inquiry; instead of that consummation in which causal effect was once presumed to come to rest.

In other words, teleological reasoning had to be replaced by a Darwinian approach, with algorithmic, cause-and-effect analysis. Veblen rightly recognised the revolutionary implications of Darwinism for science in general and economics in particular. Much later the biologist Ernst Mayr (1964, p. xviii) wrote: 'It has taken 100 years to appreciate fully that Darwin's conceptual framework is, indeed, a new philosophical system.'

While Spencer inspired a distinctive social ontology for Marshall's work, which different radically from that of other neoclassical economists by emphasising the development of individual diversity, Spenerian evolutionary principles were inadequate for Marshall's project. It is now realised that Darwinian principles can overcome these limitations and be generalised to the social domain.

Much of modern evolutionary economics takes its cue from Richard Nelson and Sidney Winter's (1982) classic book. They employed Darwin's principles of variation, selection and retention (or replication) but dared not call them Darwinian. (They have subsequently rectified this omission.)

It took over twenty years for Darwinian principles to be generalised in a form that was suitable for economics and other social sciences (Hull 1988, Aldrich et al. 2008, Stoelhorst 2008, Hodgson and Knudsen 2010). If the 'Mecca of the economist' (Marshall 1920, p. xiv) still lies in economic biology, then modern generalised versions of Darwinian principles must be considered as possible meta-theoretical frameworks. Only time and much further work will tell if a Darwinian meta-theory can serve as a basis for a new mode of economic theorising.

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