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Capitalism: restless and unbounded? Some neo-Polanyian and Schumpeterian reflections

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This paper first explores the notion that the limitlessness of knowledge is a privileged source of the restlessness of capitalism [Metcalf, J. S. 2001. "Institutions and Progress." *Industrial and Corporate Change* 10 (3): 561–586; 2002. "Knowledge of Growth and Growth of Knowledge." *Journal of Evolutionary Economics* 12 (1): 3–13; 2004. "The Entrepreneur and the Style of Modern Economies." *Journal of Evolutionary Economics* 14 (2): 157–175; 2010. "University and Business Relations: Connecting the Knowledge Economy." *Minerva* 48 (1): 5–33] when combined with incentives of entrepreneurialism in a market society. Metcalf gives a central paradigm of evolutionary economics a distinctive turn, with knowledge the pre-eminent source of variation, and markets the primary arena of selection. The paper engages this approach with a neo-Polanyian approach of 'instituted economic process', in which the variation and selection dynamic is itself seen as instituted within a particular historical economic context. The paper develops a critique of the evolutionary paradigm firstly by suggesting variations in instituted 'economies of knowledge' within a multi-modal conception of capitalism. Further breaking with the bipolar variation-selection paradigm, the paper argues that there has been a significant role of the state as a distinctive source of variation and selection in innovation and economic transformation. This leads us finally to analyse the shifting place of economy in society and polity, and the strategic responses in the USA, Brazil and Europe to the historically novel conjuncture of peak oil and global climate change, as a further source of variation. We conclude that a choice between evolutionary and historical approaches to innovation and economic transformation is a false one, once a universalising and unbounded paradigm of variation and selection is abandoned.

Keywords: evolution; variation and selection; instituted economic process; multi-modality

Capitalism can never be at rest because understanding and knowledge are never at rest and never can be, given the rules of the game. The economic system is restless because knowledge and understanding are restless. (Metcalf and Ramlogan 2005)

Capitalism is restless because knowledge is restless. (Metcalf 2001)

1. Introduction

The view that capitalism is unboundedly restless because of the essentially unlimited novelty-generating creativity of knowledge is a distinctive and abiding theme running

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through the core of Stan Metcalfe's work over recent years (Metcalfe 2001, 2002, 2004, 2010; Metcalfe and Ramlogan 2005). When aligned with a Schumpeterian view of entrepreneurialism, where novel combinations of ideas translate knowledge into market innovations (so creating opportunities for profit-making by upsetting the existing orders of market activity), capitalist economies are distinguished by their uniquely and endlessly autocatalytic dynamism. As Metcalfe insists 'capitalism in equilibrium is a contradiction in terms precisely because the growth of knowledge cannot be meaningfully formulated as the outcome of a constellation of equilibrating forces' (2002).

This paper is an outcome of an encounter between this vision of the restlessness of capitalism and a neo-Polanyian economic sociology. Broadly speaking, this encounter addresses a shared central question of the dynamics of economic transformation and stability, which could be condensed, perhaps problematically polarised, into the binary: evolution or history? In this paper, this question is framed in relation to the central evolutionary concepts of variation and selection. If we remain within the domain of political economy, this dual-process dynamic can be built around a source of variation ascribed to one category of actors and a source of selection ascribed to a strongly differentiated one. The paradigmatic case would be the entrepreneur or innovating firm as the source of variation, and a market of multiple independent users or consumers selecting from among alternative variations. We can term this sharp differentiation between types of economic actors, the one variators, the other selectors, as an ontological divide, economically speaking. At the other extreme, where there is competition or collaboration between economic actors exhibiting very similar dynamic processes of variation, the outcomes of their interactions may result in variation outcomes that persist and grow, others that shrink, or disappear. Economic competition and divergent development between states, or variation in the collaborative production of public goods, might stand as examples. In between these two extremes, there are many forms of economic organisation exhibiting forms of differentiation and interdependency, which might support some distinctive processes of variation and selection distributed between actors, including user-producer interactions (Lundvall 1988) or routines within firms (Nelson and Winter 1982), but without the sharp ontological divide of the paradigmatic case.

Metcalfe's evolutionary economics approach, stressing the unceasing evolution of capitalist-market economies, relies on the hallmark dynamic of variation and selection. In his distinctive version of evolutionary economics, knowledge, and especially the knowledge of a few individuals, is the primary source of variation, and markets the central arena for selection, and temporary order (as opposed to equilibrium) in the coordination between sellers and buyers (Metcalfe 2012). Whether as model or metaphor, the evolutionary vision of change is articulated around an ontological divide between a source of variation, on the one side, and an environment of selection, on the other. Knowledge creation is disruptive variation,¹ markets are ordering. In this vision of evolutionary change, Metcalfe (2010) accords a subsidiary yet significant role to the non-market aspects of capitalist economies, in terms of role of the state firstly in the development of the knowledge base and education, secondly in terms of instituting the 'rules of the game' without which markets could not operate. In this latter respect, he is clear, for example, that markets are not, even cannot be, left to their own devices (Metcalfe 2012). Finally, in this pastiche summary, Metcalfe's restlessness of capitalism is unbounded in that there are no limits to market creation and destruction. The boundlessness is a boundlessness of the inherent curiosity and creativity of knowledge. There are no limits to growth, because there are no limits to knowledge to either disrupt an historically temporary (in evolutionary scales) order, or to overcome obstacles to progress.

A neo-Polanyian, ‘instituted economic process’ (IEP) approach, applicable to capitalist and pre- or non-capitalist economies, starts with a view that processes of human transformation – transformation of the qualitative characteristics, the place, the control over, and the use of, an entity – only emerge as economic within societies when they are articulated together, so becoming respectively forms of production, distribution, appropriation, and consumption (Harvey, Quilley, and Beynon 2002; Harvey 2007). This Polanyian view thereby requires an understanding in terms of the economy’s place – and shifting place – *within society*. And to that must be added, the varied and shifting place of the economy *in nature*. This neo-Polanyian perspective draws upon Polanyi’s (1957) later anthropological work, rather than the Polanyi of *The Great Transformation* with its concepts of a double movement of state regulation and self-regulation of markets or ‘embeddedness’, with which Polanyi is more commonly associated. Following classical political economy, where resources such as land as a natural endowment formed a central theoretical place within their political economy, the IEP approach suggests a boundedness of economies, and an interdependence between economy and society, economy and nature, as a significant source of variation. One only has to think of the significance of the place of oil reserves, or the fact that the USA passed its peak oil in the early 1970s (DeFeyes 2001) to recognise the significance of this boundedness as a source of variation in economic organisation, and indeed as a shaping context for innovation. Whether this boundedness should be added to a growing list of selection environments is a point we return to later. In terms of the economy’s place within society, the historically and geographically variable role of politics and the state in shaping the direction of economic transformation can also be seen as a further source of variation, and again a shaping context for innovation and, as we shall argue, much more than that.

The fundamental underlying aspect of this approach, however, is that there are historically emergent dynamisms (for stability or autocatalytic transformation) of economic organisation, rather than general laws. To put the point crudely, the dynamism and innovation of pre-industrial capitalist economic organisations – to which there is now much testimony – had very different processes of variation and selection, if we stick with the evolutionary language. In IEP terms, specific dynamics of variation and selection may be said to be instituted with particular historical capitalist-market economic organisations, spatially and temporally bounded. But we then need an understanding of how ‘laws of variation and selection’ are themselves open to historical transformation. An IEP approach takes a strong position that there are no universal economic laws, whether evolutionary or other, either across historical epochs, or within the historical period of capitalist economies since the industrial revolution, or, indeed, across all post-industrial capitalist economies.

Taking this radically historical and anthropological approach to change and stability in economic organisation, Polanyi had proposed different processes of economic integration and order (redistribution, reciprocity and market exchange). In developing his approach, and here confining our considerations to capitalist political economies, this approach facilitates understanding of the dynamism of non-market economies, which, we argue, are co-constitutive of a multi-modal character of advanced capitalist economies. Below, we illustrate this analysis in respect to ‘economies of knowledge’. But, in more general terms, multi-modality embraces a variety of scale and scope of non-market (state, domestic, communities of practice, etc.) as well as market economic organisation, each of which is open to growth and innovation. The plurality of economic organisational dynamisms, their interdependencies and interactions, undermine any simple, or binary, ontological divide between a source of variation and an environment of selection.

Finally, by insisting on dynamisms as the instituted properties of emergent economic organisation, the IEP conception of variation entails dynamisms with a spatial as well as temporal fix. Economic organisational dynamisms have developing spatial scales, and as such, are continuously colliding with other emergent economic dynamisms, so inducing further variation. As against some more taxonomic approaches of ‘varieties of capitalism’ (Whitley 1999, 2000; Hall and Soskice 2001), an IEP approach therefore concerns itself with processes of variation and scale formation both within and between emergent economic organisations, micro-local-national-regional or global. If one reflects on the 2007–2008 and ongoing financial crisis, one significant dimension has been the conflict between different banking systems and financial markets, which in turn is generating further variation in organisation of the financial sector worldwide, in a multi-scalar universe. In that sense, for an IEP approach, innovation, and yet more narrowly, market innovation is but one source of variation in economic processes and their organisation. So, once more, by adopting an approach to emergent dynamisms and scale formation of their economic organisation, further dimensions of variation become significant for analysis in a way that departs from the bipolar variation-selection environment evolutionary paradigm. If one brackets off a given historical market economic organisation at a certain scale, processes of variation and selection might be identified within it. But then not only are there other emergent market organisations, with different processes of variation, but also interactions between them inducing further variation in a multi-polar, multi-scalar universe. And then we add multi-modality into the mix, and a plurality of non-market processes of dynamic variation. And, we argue, we end up with histories of economic organisation, emerging and disappearing dynamisms of varying scales, and the study of economies becomes an historico-geographical discipline.

Clearly, in this paper, we can only explore this continuing encounter between evolutionary and neo-Polanyian approaches by touching on some of the key points of intersection: knowledge, the state and multi-modality; and the place of economy in nature with respect to finite resources and climate change. The overarching thread developed through these sections concerns the multiple sources of variation, of appearance and disappearance of forms of economic organisation, and hence a questioning of the evolutionary paradigm as characterised above.

We start with a comparison between Metcalfe’s view of the role of knowledge and an ‘economies of knowledge’ perspective developed in our research on the revolution in biological sciences from the 1980s (Harvey and McMeekin 2007, 2010). The central issue here is whether knowledge creation is exogenous to the economy, taking place in a private space, rather than constituting a non-market, public economy endowed with its own distinctive dynamic, hence a distinct source of variation.

We then turn to an argument that different state responses to ‘peak oil’ and climate change – responses to shifting relation between economies and nature – are themselves a significant source of contemporary economic variation and innovation. From our research on biofuel innovation trajectories in the USA, Brazil and Europe, we will argue that differences in the extent and nature of political direction are central to understanding the ‘directed evolution’ of a passage to a low-carbon economy. As such, the relation between polity and economy must form part of our accounts of historical change. Pursuing this line opens up the Polanyian view of the ‘shifting place of economy in society’, that is, that the role of the state, and hence also variation between states, has historically changed over time, now more, now less directive of economic transformation.

Finally, we draw together the overarching thread by questioning the bipolar variation-selection environment version of evolutionary economic thinking, and suggesting that

there could be a common terrain by agreeing that evolution is history, and history is evolution.

2. Knowledge and economy

We would begin our conversation between Metcalvian evolutionary economics and a neo-Polanyian economic sociology perspective by a shared affirmation of the centrality of the growth of knowledge, especially the emergence of science and technology, and capitalist economic organisation and market transformation. Recently once more highlighted by Mokyr's (2009) *The Enlightened Economy*, experimentation in knowledge, including the technologies of knowledge production, was intimately connected with experimentation in a new economic organisation, new products, and new markets. An enduring symbol of this new combination were the innovative public demonstrations and institutions surrounding Boyle's experimentation with carbonated water and the formation of Schweppes, and the first commercial markets for the then novel beverage (Golinski 1992).

There are three main issues we focus on here: knowledge creation as a source of novelty, hence variation; knowledge creation as inside or outside the economy, or as inside or outside the *market* economy; and, the relationship between knowledge creation, invention and innovation (at the core of a Schumpeterian view of entrepreneurialism).

For knowledge creation, Metcalfe asserts what he calls a 'foundationalist' position, by which he means that 'only individuals can know' (Metcalfe 2001; Metcalfe and Ramlogan 2005). Although presented as methodological individualism, it would perhaps be more accurate to describe this position as ontological individualism, because only individuals have a capacity to know, founded on the 'electro-chemical responses in the individual brain'. Metcalfe takes a strong position on this, to the extent that a process of translation is required from tacit, even unconscious, unframed knowledge, into public and communicable information. But there are two strands to this ontological individualism that we would like to tease apart for their different implications for an evolutionary perspective: an epistemic function, and a variation function. The first attests a position on how knowledge is generated, its originary source in individuals. The second attests the fact that every individual is different, and from that difference in individual perspective, experience, memory and knowing activity, variation arises.

Taking the epistemic function of ontological individualism, at first there appears to be a very sharp, even dichotomous, view of knowledge as tacit and private, and information as public and only more or less effectively subject to the reverse translation of information back into knowledge of other individuals. However, particularly in Metcalfe's reprise of Adam Smith's division of labour among specialists in knowledge production (chemists, engineers, physicists, biologists ...), he builds up a third significant epistemological category, namely, understanding. Once there is division of labour, at any scale, there has to be a work of coordination to establish mutual understanding across the divisions, entailing an elaboration of language, concepts, shared methodologies, demonstrations and proofs. There is a process of instituting order – coordination – in knowledge (Metcalfe 2012), parallel to order in markets – a different form of coordination. In our view of economies of knowledge, this process of developing understanding is at the core of generating new knowledge, as we shall elaborate below. So, here we choose to put in brackets the attribution of knowledge creation exclusively to individuals, and retain a concept of understanding (in addition to information) hoping that the difference between understanding and knowledge is largely semantic.² We wonder how essential the ontological individualism of the epistemic function is to an evolutionary economic account, given that for any such putative knowledge to become

economically effective it has to become embodied in understanding and information. In particular, growth in knowledge, or the accumulation and progress of knowledge, appears to be manifest primarily in the public domain of understanding. And we certainly adhere to a strong version of progress of knowledge on this basis.

However, the second, and connected, variation function of ontological individualism proposes that differences in perspective arising from the uniqueness of experience of each and every individual, is critical for the restlessness of knowledge. This is the 'micro-diversity' which underpins both knowledge generation, and significantly a Hayekian view of markets as the institutions capable of coordinating micro-activity through their process of selection. Here we see a central evolutionary perspective of diversity as variety-creating and a selection environment, the market and its instituted rules and norms, as source of spontaneous, bottom-up, and temporary, order.³ The role this concept plays for a critique of equilibrium theory is of course significant, because the concept is used to suggest the limitless openness of any one position to challenge and change, and the absence of any possibility of arriving at a steady state of a homogeneity of agents, endowed with perfect information and uniform rationality. However, in parallel to our remarks on the epistemic function of ontological individualism, we wonder how essential individualism as such is to this argument. For, accepting that diversity of perspective generates variety at any scale of social entity, from the individual to the nation state and above, the key, and empirical question is what kind and scale of variety makes a difference. With individual knowing, only when scaled up into a level of shared understanding does growth of knowledge begin to make a difference, notably, for example, within a scientific community. Equally, many individual differences are insignificant and transient variations, and the empirical question is one of how variations achieve scale and impact for challenging existing orders, epistemic or economic. So, we share strongly a path-dependency view of variation, where entities at whatever scale have different trajectories, perspectives and orientations, hence are capable of challenging and counterposing the positions held by other entities.

Summing up our reflections on this first issue, we can distinguish between two processes of variation: novelty creation and conditioning by differential position in space and time. We are suggesting that for both processes of variation, scale matters, and the process of scaling up, and formation and institution of scales of variants, from individuals, through organisations, to states and supra-state organisations, is an empirical field for analysis.

Turning now to the second issue, namely, whether knowledge creation is endogenous or exogenous to economies as a source of restlessness, it appears that ontological individualism of knowledge takes knowledge creation out of economic activity. At least, that is our reading. However, Metcalfe is clearly also advocating, although not in these words, a multi-modal view of understanding and the economy. On the one hand, entrepreneurial knowledge, the knowledge of markets, as well the ability to combine novel ideas, with their realisation in productive processes undertaken by firms, is knowledge firmly placed within economic activity. It is critical to turning inventions into innovations (Metcalfe 2004; Knudsen and Swedberg 2009). On the other hand, the existence and expansion of the university sector, the development and accumulation of knowledge (understanding) in the public domain, is a critical resource available for mobilisation by entrepreneurial knowledge. A complex picture of the interdependence between non-market and market institutions is at the very centre of a complex adaptive systems perspective (Metcalfe 2010). There is a sense, perhaps no more than a question of emphasis, that public knowledge is a resource to be drawn upon by the primary engine of capitalist growth, the entrepreneur and the market. We shall return to that point. But the hanging question surrounds where to place individual and private creativity of knowledge, as an economic or extra-economic activity.

And so finally, in this schematic account, the third issue relates to the Schumpeterian argument for the difference between invention and innovation, with only the latter leading to the unmaking or economic orders, as a consequence of entrepreneurial activity. Here we have no argument with this principle as applied to the challenging of market orders (Harvey and Metcalfe 2010), and indeed we have suggested that there is a useful synthesis between Polanyian and Schumpeterian processes of creative destruction: innovation in markets as institutions, transformations of rules and norms governing market behaviour, enhance the account of markets as arenas for competition between alternative commodities. A case study of genetically modified (GM) tomatoes is an interesting example of the feedback loops between technological development, market innovation, and basic science (Rosenberg 1994; Harvey, Quilley, and Beynon 2002). An industry–university collaboration developed a technique for retarding the ageing, and rotting, of tomatoes, so leading to higher quality, lower-priced tomato paste. Entrepreneurial knowledge, especially led by supermarkets and their closer-to-consumer market sensitivities, resulted in a successful launch of GM tomato paste, with full transparency of information. The science of gene-silencing and metabolic pathways was then cutting-edge genomics, co-evolving with the development of a biotechnology and its development through to market innovation. But then, politics of the markets intervened over Schumpeterian market selection, culminating in a ban on all GM products. In contrast to most of the rest of the world, Europe became a virtually GM-free zone, affecting both its public science base and market innovation in the region.

The Schumpeterian innovation process presents a view in which the market is the only selection environment within which positions are challenged, and new economic orders are established. In this respect, we suggest that the emphasis on market innovation is one-sided in underestimating the importance of non-market innovation with which there are often strong interdependencies and interactions. Indeed, particularly in the realm of medical practice and organisations, as Metcalfe himself has shown, the case of stents and intra-ocular lenses exemplify technological innovation (Metcalfe, James, and Mina 2005; Mina et al. 2007), combined with service and practice innovation where the non-market selection environment operates in quite different ways from markets as typically represented. Here emphasis needs also to be placed in the other-than-normal way round, namely, the dependency of innovatory non-market clinical practices on the adoption of market innovations of commercial products. Our own work on multi-modal economies of knowledge, illustrated below, further develops this point.

Indeed, in our understanding of the major knowledge and economy question explored here, the dynamism of the growth of knowledge and the institutions that surround and support it, require a more developed analysis of non-market ‘economies of knowledge’. Adopting a neo-Polanyian ‘IEP’ framework, we argue that there are not only market ‘orders’ which may be restlessly and continuously challenged, but also non-market ‘orders’ equally subject to processes of historical transformation. The epistemological revolution in biological sciences was also a period of great turbulence in the ‘economies of knowledge’, resulting in public economies of knowledge, understood in neo-Polanyian terms as new configurations of public production, distribution, appropriation, and consumption.

This framework permits us to develop a more substantive analysis of ‘economies of knowledge’ as a non-market dynamic of restless change. In *Public or Private Economies of Knowledge* (Harvey and McMeekin 2007), we arrived at two major conclusions. Firstly, there have been new instituted processes of production of knowledge, on an unprecedented scale, exemplified most obviously by the Human Genome Project, but also by a huge range of other developments across all the ‘-omics’. We would argue that not only have

there been major discoveries and radically new conceptual developments, but also that processes of discovery and conceptual development have undergone radical change, with the emergence of new divisions of labour, particularly between biology and computer science, and hence novel combinations of disciplinarity. Parallel to transformations in knowledge production, there have been simultaneous changes in the relations between producers and users. Whether in terms of the new bio-resources and databases or the new bioinformatic tools (the equivalent of scientific technologies), there has been growing polyvalence of use by different user groups, corporate pharmaceutical, medical public sector, and a range of different scientific disciplines: a given gene sequence is put to many purposes. The *use* of these tools and data may be for the further production of new tools and data, as well as a wide range of uses for non-epistemic purposes, such as drug discovery or medical diagnosis. As the third process subject to reconfiguration, there has been the revolution in distribution, based on the digitisation of biodata of all kinds, images, sequences, simulations, and so on. Perhaps the most extraordinary example of this innovation in distribution is the simultaneous 24-hourly upgrade of global genomic data in the three centres of GenBank, the European Bioinformatics Institute, and the DNA Data Bank of Japan in Japan, a new global distributional logistics of knowledge. But finally, to complete our quartet of poles constituting the new public economies of knowledge, there has been a remarkable process of innovation in modes of public control and appropriation of the new knowledge. The commons is not just a blank space out there, into which everyone can graze whatever animals they like, when and how they choose. In a break from the norms of peer review in scientific journals, there have been new rules and norms of publication governing the quality of data and the temporalities of data deposition. New institutions and organisations have arisen to govern and coordinate the ontologies and languages in which biological knowledge is expressed, with many science community organisations exercising control over this distinctive new form of public good (e.g. the Microarray Expression Data Society, the Gene Ontology Consortium, and the Genomic Standards Consortium). We would argue that this is a process of knowledge creation, linked to a public mode of coordination. To put it quite crudely, the public commons contrasts with the coordination of markets, where incompatible software or hardware packages compete for market position in a ‘spontaneous’ bottom-up fashion. Such market-typical heterogeneity would be disabling to the public commons. Coordination and control over the public domain of knowledge is more than an infrastructure of mutual understanding, but as a process it generates new conceptual and methodological development. Communities of practitioners (a plurality of publics) develop commonalities of understanding, which then raise new scientific questions, leading to further developments in attempts to achieve consistency and coherence. To emphasise, these public economies of knowledge, although generally state-financed, are not state-controlled economies. In our analysis, therefore, we depart quite strongly from Merton’s or David’s analyses of the public domain as if they were simulacra of market competition or principal-agent activity (Merton 1957, 1988; David 2004, 2008). So, we suggest that public economies of knowledge (configurations of production, distribution, appropriation, and use) can be analysed in their own right, with their own distinctive dynamic properties, as part of a wider understanding of multi-modal capitalist growth. The point to emphasise concerns the plurality of non-market economic dynamisms. Indeed, we would argue that this perspective on economies of knowledge gives greater weight to the idea that the restlessness of capitalism is significantly driven by the restless dynamics of economies of knowledge.

And this leads to the second major conclusion. Within capitalist economic history, public economies of knowledge do not develop autonomously, in a kind of parallel universe to market economies. Along with the development of the new public institutions of knowledge,

the most striking feature of the turbulence of the revolution in biological knowledge was the radical uncertainty as to whether the public economies of knowledge would shrink to near zero, in the face of vibrant competition to establish commercial economies of knowledge over genomic and other biodata, as well as the new scientific instrumentation of bioinformatic tools. Simply put, would the human genome and the means of its discovery be public or private property? There was a period during the early 1990s, when it appeared it could go either way. But as the history unrolled, there was a fraught and unstable process of differentiation and interdependence between public and private economies of knowledge, with the latter generating multiple new market innovations in products and services. Fundamentally, innovations in the public economies were responses and reactions to innovations in the private economies, *and vice versa*, in a multi-modal dynamic. The unstable ‘frontier’ between the public and private economies of knowledge remains unstable and as such a source of further restlessness. The emergent economic orders – and causalities – can only be understood as a radically historical process. We park for later the question as to whether this can be best understood in variation and selection terms, given that in this account markets are as much selected for as selecting. What ended up from the process of differentiation and interdependence between public and private, defined the bounds of the market – temporarily. We will introduce other examples of markets and other forms of economic integration as objects of selection, to move away from any simple ontological divide between units of variation and selection environments typical of the stricter biological model of evolution (Hodgson and Knudsen 2006).

3. Economy, polity and nature – capitalisms re-directed?

In this section, the historical coincidence of two distinct challenges to economic growth, each concerning a shifting relation between economy and nature – namely, global climate change and the depletion of a primary finite energy resource (oil) – are considered as further distinct sources of variation, arising from strategic political responses in different regions of the world. In Polanyian terms, this heralds a conjunctural shift in the place of economy in society and nature that goes beyond the paradigmatic evolutionary dynamics of firms and markets. The historical precedent of the major economic and social impact of the opposite climate change effect, the Little Ice Age from the fourteenth to the late eighteenth century (Fagan 2001; Ruddiman 2007), is only suggestive of the scale of the challenge faced by global warming at 2°C or above in the twenty-first century. The challenges to innovation arising from peak oil may seem more amenable to market incentives, but earlier energy and materials transitions have all been driven by the addition of new resources, from charcoal to coal, from coal to petrol and nuclear, and so on. The energy system transformation of today is thus under a very different constraint than that discussed for earlier transformations (Huberty and Zysman 2010). We can agree with Mowery, Nelson, and Martin (2010) that the circumstances and challenges of climate change, and consequently the appropriate policy responses, are quite different from the space race of the Apollo mission, or the ‘Manhattan Project’. However, they draw on past state responses to economic challenges also quite different in scale and urgency from the current conjuncture, and with Moreau (2004), stress similar limitations on governmental knowledge and capacities in comparison to market actors.⁴ Here, by contrast, we point to actual governmental responses to this new conjuncture in different regions as a source of variation, showing both different extents and different orientations and objectives, of strategic governmental direction of innovation in the USA, Brazil and Europe.

However, the other side of the coin to strategic political responses to these challenges as a source of variation, concerns the extent and nature of the lock-in, on a global scale, to the petrochemical technology platform (Unruh 2000). Critical here is the governmental lock-in to existing energy and agricultural economies, both narrowly in terms of public infrastructural investments or fiscal revenues, or more broadly, a lock-in to inherited policy perspectives – including underpinning assumptions of the limits of capacities of states to shape markets and innovation in the dynamics of growth in capitalist economies (Moreau 2004; Mowery, Nelson, and Martin 2010). The examples of Brazil, the USA and Europe we present below, in relation to renewable transport energy, are as much about lock-in, even entrapment (Walker 2000) as novel strategic political direction of innovation.

In relation to climate change, existing markets, including future markets, do not constitute selection environments sufficient to bring about a shift in energy and agricultural systems. The central implication of the analysis developed by Stern (2006) is that future economic risks are effectively invisible in current markets, and the distribution of future risk across populations and regions surpasses any temporal or geographical scale of spontaneously emerging market incentives to innovate for sustainability. As Ashford (2002) has argued, ecological modernisation through market-led innovation (Spaargarten and Mol 1992), on the basis of precedent, is unlikely to occur because of the temporally and spatially unequal costs and benefits arising from climate change and its mitigation. There is a disconnect between those economies suffering the greatest and earliest effects of global warming, and the economies most responsible for anthropogenic climate change.

The market selection environment related to the challenge of peak oil – in spite of major market signals in the shape of oil price spikes, has also so far failed to induce innovation for radical energy systems change. The 1970s oil shocks can be seen as a prelude or harbinger of progressive depletion of finite resources, and point to parallels with previous interruptions of supply during wartime – and the first stages of our Brazilian study will bring this to the fore. But these were temporary, and at the extreme end of politically manufactured resource constraints. As is already clear from OPEC's political strategies at the Copenhagen UN Climate Change Conference in 2009, the use and availability of fossil fuel to the market will involve a dynamic of political, economic, and material resource endowment characteristics: who controls what type of oil, where. There has not been, and will not be, any simple physical 'peak oil' created by technologically available means of extracting finite physical resources (Cavallo 2005; Sorrel et al. 2009). The ecological disaster of the Deepwater Horizon blowout in the Mexican Gulf in 2010 may well change what are considered to be available oil reserves, and will certainly make similar deep-ocean reserves economically less attractive. Extreme turbulence in prices of oil, swings from \$148 per barrel to \$35, and back to \$75 over the space of a year, and more importantly swings from growth to severe economic depression (Hirsch, Bezdeck, and Wendling 2005), are already reflections of what might happen in the absence of a strategic political drive to develop renewable energy. Market-driven innovation on its own has already proved insufficiently radical or urgent in the face of petrochemical depletion – and many have argued that even with strong market signals, economic and political actors have largely been in denial (Leggett 2005). Even granted the academic consensus on the negative relationship between oil price rises and GDP growth (Jones, Leiby, and Paik 2004), markets have failed to induce any adequate strategic response by market actors to shift away from oil dependency. As Mowery, Nelson, and Martin (2010) have argued, investment in R&D in response to oil price shocks has until recently been reactive, short-term, and neither strategic nor forward looking.

We turn now to the three major conclusions arising from our biofuels research, which compared innovation strategies in three major regions, the USA, Europe and Brazil (Gee and

McMeekin 2011; Harvey and Pilgrim 2011, 2012). Firstly, to varying degrees and in different directions, the USA, Brazil and Europe have developed strategic direction of innovation in response to the differently weighted objectives of global climate change mitigation, energy security, and economic development. Secondly, the major explanation for the variation between regions in innovation strategies rests at the level of political direction and the correlative political and market lock-in to fossil-carbon energy. Thirdly, it will be evident from the cases that there are considerable path-dependencies, lock-ins or entrapments, related to contrasting natural resource endowments of the three regions, and the significant power of agricultural lobbies: corn to ethanol in the USA, sugar cane to ethanol in Brazil, and rapeseed to biodiesel in Europe. It will also be clear that, with the partial exception of Brazil and its promotion of new power-trains, there has been a continuing socio-technical lock-in to distinctive regional vehicle manufacture and transport infrastructures, with their attendant tax revenues, in the USA and Europe.

3.1. *Brazil*

Brazil has been the longest established major producer and user of bioethanol, under a strategic political direction of the ProAlcool programmes initiated as a consequence of the oil price shocks of the 1970s (Goldemberg 2008). The driving force behind the innovation during the first 20 years was energy independence from reliance on imported petrol. From the beginning of this century, additional strategic goals have been to expand international markets for renewable fuel, to promote sustainability through greenhouse gas emission, and to sustain rural employment and eradicate poverty. The innovation strategy has been directed at all phases of the production of fuel. The government has supported the creation of improved varieties of sugar cane, including the development of GM sugar cane, with different inheritable traits. Mechanisation of harvesting is progressing to minimise the impact of pre-harvest burning of fields required for manual harvesting. Biorefinery has progressed through several stages of innovation, but currently is self-sufficient in energy through generating bio-electricity by using sugar-cane residue (bagasse) as a fuel, now also contributing 1.5% of electricity supply to the national grid. Additionally, fertiliser co-products (vinasse) contribute to greenhouse gas (GHG) savings and reduce pollution to the water table. Current state funded research programmes (the FAPESP BIOEN programme) are supporting research into biopolymers and other chemical building blocks, on course for integrated biorefineries. The government initiated the development of the first transport fleet to run on 100% ethanol following the 1979 oil price shock, but more recently, Flex-Fuel Vehicles (FFVs), capable of running on 100% bioethanol, petrol or liquid gas. Currently, bioethanol contributes 40% of transport fuels, and over 80% of new cars purchased are FFVs. The bioethanol industry supports 700,000 jobs directly and a further 200,000 jobs indirectly, 100 times greater employment by unit of energy than oil (De Almeida, Bomtempo, and De Souza e Silva 2007). It would be mistaken to describe sugar-cane ethanol as the first generation, given both the progressive stages of innovation already realised, and the projected increases in productivity at all phases of production. GHG savings of current generation sugar cane, with co-products, exceed those anticipated by 'second-generation' lignocellulosic bioethanol, and the development of bio-ethylene as a co-product will increase that advantage (Brehmer and Sanders 2009; OECD 2008). Brazil represents the most advanced country in the world for energy security and sustainability. It has achieved this position only as a consequence of political innovation strategies developed over the long term, encompassing funding of basic science, commercial R&D, and market shaping through use of incentives. Even if its political objectives have been primarily those of energy security and

economic opportunity, Brazil has ‘accidentally’ achieved higher levels of renewable and ecologically sustainable transport energy than any other country or region.

3.2. *The USA*

The main expansion of bioethanol production in the USA occurred later than Brazil, taking off around the turn of the twentieth century, although an earlier bioethanol industry had been promoted by the US government in response to the 1970s oil shocks, as with Brazil. The USA had passed its own peak oil in the early 1970s (Defeyes 2001), and was becoming increasingly dependent on imported oil, thus raising issues of both energy security and availability. The annual trade deficit for oil had risen from \$27 billion in 1987 to \$100 billion in 2002 (International Energy Agency 2006), and the costs and vulnerability of securing Middle East oil had escalated. The principal objective shaping the politically sustained innovation pathway in the USA was initially overwhelmingly that of energy security and independence, only more recently supplemented by objectives of GHG emissions reduction, and concerns over environmental sustainability. A succession of legislative and funding measures by the US government, led by the Departments of Energy and Agriculture, have established long-term strategic goals, and significantly acted on both market demand and on development of supply for bioethanol. The 2000 Biomass R&D Act was followed by the Energy Policy Act of 2005 and the significantly entitled Energy Independence and Security Act in 2007. Mandates requiring substitution of petrol by bioethanol are ambitious –20% reduction of petrol use in 10 years, and 30% biofuel for transport by 2020 of which two-thirds are to be ‘second generation’ by 2022. Although below levels achieved in Brazil, these mandated markets are considerably above those aimed at in Europe. On the supply side, a multidimensional and large-scale investment programme has been established in fundamental science, notably systems biology, and in technological development, both directly by government finance and by corporate-government alliances. A loan guarantee scheme underwrites risk on capital for new companies emerging in the production of lignocellulosic bioethanol, or in high risk areas, such as algal or bacterial derived biofuel. The Genomics Systems Biology Program for developing biofuel, biorefinery and plant technologies demonstrates a long-term commitment to scientific and technological development. The Energy Bioscience Institute comprising the Universities of Illinois, Urbana–Champaign and the Lawrence Berkeley National Laboratory with BP, supported by \$500 million from BP, and dedicated to developing second-generation biofuels exemplifies the effects of the innovation environment created by the current policy (Blaschek et al. 2009). As with Brazil, although the main stated objective of this strategic policy framework has been energy security and independence, the ‘collateral benefit’ especially from second-generation biofuels has the potential to reduce competition for land with food uses, and result in significant GHG emissions reduction.

3.3. *Europe*

Europe stands out as the major producer of biodiesel in the world and contrasts with the other major biofuel regions in the dominance of biodiesel in terms of production and use (McMeekin et al. 2010; Harvey and Pilgrim 2012). Of this biodiesel production, over 80% is derived from ‘home-grown’ rapeseed. The principal explanation for the contrast with other regions is the rapid ‘dieselisation’ of the European vehicle fleet, with consumption of diesel rising from 45% of transport fuel in 1990 to 63% in 2005 (European Biodiesel

Board). Currently, over 80% of all new vehicles purchased in Germany are diesel, with similar levels for many continental European countries.

As with the other two regions, the rapid growth in biodiesel production and use in Europe can be attributed to major policy initiatives taken at the European level, and then expressed in a variety of policy measures in different European countries. In contrast to the other regions, the principal policy objective guiding European strategy has been to address commitments made under the Kyoto Protocol by reducing GHG emissions (Londo and Deurwaarder 2007). Policy at the European level sets long-term targets, and mandates for levels of biofuel use, but considerably below those aimed at or achieved in the other regions. The first targets set in 2003 aimed at achieving 5.75% of biofuels for transport fuels by 2010. The actual level of UK replacement of petrol/diesel with biofuels stood at 2.6% in 2009 (Renewable Fuel Agency, 2009), far below Germany (7.3%; Government of Germany, 2008), France (3.57%; French Authorities, 2008), and Sweden (4%; Swedish Government, 2008). Following the Searchinger controversy,⁵ the 2009 Renewable Energy Directive and Fuel Quality Directive revised the targets to 20% of transport energy from renewable energy by 2020, with only 10% required to be supplied by biofuels or other 'green' transport energies. In marked contrast to the other regions, Europe has pioneered regulation for sustainability in its treatment of biofuels. The Renewable Energy Directive requires 35% GHG savings from now until 2017, and 60% GHG savings from new installations and processes thereafter. A review, and possible tightening of sustainability criteria, is projected for 2013. The Fuel Quality Directive requires the continued provision of petrol with a *maximum* of 5% ethanol blend until 2013, and the gradual phasing in of 10% bioethanol (E10) over the coming years. It also requires a 6% reduction in GHG emissions from units of energy supplied for transport fuels by 2020. Conveniently for the European rapeseed industry, rapeseed methyl ester biodiesel currently just achieves the required savings (according to current default values listed in Annex 5 of the Renewable Energy Directive), using measures that do not include indirect land-use change.

Policy measures adopted by different European countries involve tax incentives for biofuel use and mandatory obligations, as with the Renewable Transport Fuel Obligation in the UK. But in contrast to both Brazil and the USA, on the supply side there has been no equivalent major strategic innovation programme for the development of future biofuels, in support of the relevant basic science or technologies. For example, given the current dependency on biodiesel, there has been no major programme for the development of second-generation biodiesel, such as biomass-to-liquid necessary to meet the more stringent GHG reduction requirements from 2017. Demand-side measures have not been complemented by adequate supply-side policies, leaving a considerable question mark on the achievability of either fuel-substitution or sustainability targets. Likewise with bioethanol, although there are some major bioethanol producers in Europe (British Sugar, Ensus, Tereos, Abengoa, CropEnergy), there is also heavy reliance on imported bioethanol, and little evidence of the strategic aim to move to second-generation bioethanol similar to the USA. The policy direction of biofuel production and use towards sustainability of transport energy in Europe thus risks failure in these objectives, while not even addressing the major issues of energy security and availability.

Europe presents some of the clearest evidence of lock-in, even entrapment, partly as a consequence of its complex, multi-level, political institutions and decision-making (Harvey and Pilgrim 2012). Agricultural interests and a distinctive car manufacturing investment in diesel power-trains represented by market actors, combine with a distinctive political context of environmentalist NGO lobbying to result in a limitation of strategic direction in the region, and a reliance on fossil-carbon energy by default (Pilgrim and Harvey 2010).

From the resumé of innovation in the three regions, one can observe innovation in the ‘social technologies’ directing innovation, to varying degrees and in different directions (Nelson and Sampat 2001; Nelson 2008). Different perspectives, endowments, and political systems and objectives are a primary explanation for the emergence of a new variety for transport energy in the global economy, contrasting significantly with the relatively global homogeneity of the petrochemical technology platform. The issue here is one of how to analyse the ‘shifting place of the economy in society’, or, in terms of institutions, how institutions as complex adaptive systems are adjusting *or failing to adjust* to the historically unprecedented circumstances of peak oil and climate change. This adjustment process is itself generating new variation between regions, with, as we have seen different speeds and directions of change occurring in them. The failure or limitations to change – adaptive failure presaging endangerment of this species of economic organisation – may be attributed to ‘socio-technological lock-in’. To varying degrees, there is a form of socio-technological lock-in to the typical relation between market organisation and the role of the state in regulation and science and technology policy, that is, resistant to radical and urgent adaptation. There are also major social and political interests, with institutional underpinnings, actively resisting such change, much in the way that oil majors are part of the technological lock-in. In Europe, we have seen how the political system at the level of the EU and the nation state prevents region-wide strategic direction. Major political interests representing farming have effectively opposed radical adaptation, so inhibiting the switch away from fossil fuel dependency. In sum, both strategic political responses and socio-technical lock-in of different institutional systems are a source of variation, at the national, regional and supranational scales of political and economic organisation.

4. History or evolution: a false choice?

In conclusion, we draw together the principal issues arising from our engagement between a neo-Polanyian approach and evolutionary economics arising from our research programme of the past 12 years. The two approaches share a common language and some assumptions about historical change and comparative variation. There is order and there is change, and it is ongoing. Not everything goes, and economies have both a spatio-temporal fix and an impermanency. But we want to end by raising a question: is there any principled difference between a radically historical account and an evolutionary one?

The paper has focused on the paradigm of variation and selection, which has given evolutionary economics a distinctive approach to studying dynamic processes. Accepting that an ‘instituted’ dynamics of variation and selection may indeed operate within certain market economic organisations of industrial capitalist political economies, the paper has questioned the general scope of a variation-selection paradigm, in two main aspects: multi-modal economic organisation going beyond a bipolar ontological divide between a source of variation and a selection environment; and, the conjunctural shift of the place of economy in its relation to the polity arising from climate change and oil depletion and energy security.

4.1. *Beyond the ontological divide*

We argued that the multi-modality of economies of knowledge, and, in particular, the processes of differentiation and interdependence between public and private economies of knowledge, have witnessed the creation and destruction of markets for knowledge (of genomic data, or bioinformatic tools). Evidence was presented, moreover, of newly instituted public economies of knowledge, with novel forms of public good. There are three

principal ways that multi-modality breaks with the sharp ontological divide of the evolutionary paradigm case. Firstly, there is a multiple, and complex ecology of economic organisation, market, non-market, state and non-state, with many hybrids in between. Variation within any one form of economic organisation – and we noted particularly innovation in the production and distribution of knowledge – occurs within a complex set of interactions, where the metaphor of a source of variation as opposed to an environment of selection seems a stretch too far. Secondly, the interdependency between economic modes – between public genomic databases and in-house pharmaceutical company genomic databases, for example – and the mutually stimulating dynamics of their growth, suggests both an absence of an ontological divide, and equally the lack of antithetic functionality on either side of the divide, variation versus selection.

So thirdly, and here we echo strongly Nelson's (2011) argument, the processes of variation differ in different economic modes, public, private, state, voluntary, household, etc. The example we gave is the process of control or appropriation in establishing biological databases, in order to establish common standards, languages, and ontologies. This was a cooperative, rather than competitive-selective, process to establish a shared good, nonetheless innovative for all that, in the sense of generalising throughout the population of a particular public. In Polanyian terms, there are different forms of economic integration in different economic modes, and it is for this reason that, even within capitalist economies, a Schumpeterian or Metcalvian variation and selection dynamic can be seen to be instituted only within a particular form of market organisation, bounded in scope both within capitalist economies, and more generally.

4.2. *Varying the 'laws of variation'*

The final point to make in breaking from a universal paradigm of variation and selection concerns the emergence of significant novel circumstances in the triangular relation of economy-polity-nature, arising from the conjuncture of finite resource depletion and climate change. We argue that there is a historic shift in this triangular relation, which in turn changes the dynamics of variation. Peak oil and climate change are game-changing in terms of the generation of variation. To a greater or lesser extent, politically directed innovation pathways have emerged, with diverse strategic objectives. We have attempted to explain this step change towards a more directed evolution, while at the same time pointing to historical precedents, where there were also game-changing circumstances leading to different forms of competition, such as wars between different politico-economic organisations. Peacetime economic competition and innovation processes contrast sharply with wartime innovation and competition. Yet an historical account of capitalist economic transformation is wanting if it does not include both. Of course, it is possible to argue that war economies are aberrant moments to be bracketed off, and that economic analysis can be content to deal with 'normal' times. While we doubt that argument holds water especially when considering the historical period of the Cold War (e.g. the Apollo Project), we would argue that current economic circumstances, both of peak oil and climate change, are both inherently connected to, and emergent from, economic development especially of the last two centuries. So here certainly, there can be no bracketing off. Fossil carbon and its economic utilisation have been the heartbeat of much economic transformation. And of course, its economic use is at the centre of anthropogenic climate change, an example of how economic organisation has affected the natural environment, then rebounding back on economic organisation. So the natural environment and its resources (climate change and fossil carbon) now have to be brought into the frame of a historicised evolutionary account.

Does blurring the ontological divide between varying entities and a selection environment, or abandoning the permanency or universality of the paradigm of variation and selection mark an essential difference between a neo-Polanyian historical economic analysis and an evolutionary economic perspective? Evolutionary concepts clearly remain one of the most powerful ways of thinking about much historical change. We have argued that a neo-Polanyian view of the transformation of economic organisation through innovation needs to take account of the shifting place of the economy in its triangular relation with nature and the polity: economic restlessness is a bounded, certainly conditioned, and even circumscribed restlessness. Moreover, by bringing knowledge production into the core of a multi-modal economic analysis, we have seen how there are path-dependencies, even lock-ins, to knowledge paradigms, including economics ones, which might constrain responses to novel historical circumstances. Curiosity, within economy and socio-polity, is not unconditional, unbounded. But, in analysing the boundedness of knowledge creation – or, for that matter, of economic transformation – we find further sources of variation. In that sense, stripped of the vestiges of universalising paradigms, the choice between a radically historical and evolutionary economics may be a false one, suggesting fertile ground for a continuing dialogue between the different perspectives.

Notes

1. As discussed further below, Metcalfe also suggests that mutual understanding – coordination or ‘correlation’ between disparate knowledge – also entails stability and order, as against new knowledge, which is ‘decorrelating’, and disruptive of established mutual understandings.
2. ‘For social action to be possible, for actions to be mutually supporting and collaborative, it is necessary that private knowledge becomes public understanding to the necessary degree’ (Metcalfe and Ramlogan 2005, 658).
3. ‘Capitalism is at its core a system for the decentralised generation of new knowledge in ordered patterns of economic and social change’ (Metcalfe 2001, 570).
4. Although their historical accounts of biomedical, agricultural and information technology innovation do provide ample evidence of the critical role of the state in knowledge-based economic development.
5. Searchinger et al. (2008) controversially argued that the price of food was increased by diverting land to produce biofuels, resulting in more land being brought into use elsewhere and a consequential release of GHGs from land conversion. Hence, there were no, even negative, environmental benefits to be derived from biofuels.

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