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POLITICAL SHAPING OF TRANSITIONS TO BIOFUELS IN EUROPE, BRAZIL AND THE USA

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Abstract:

Faced with major challenges of global climate change, declining fossil fuel reserves, and competition between alternative uses of land, the transition to renewable transport fuels has been marked by new modes of political economic governance and the strategic direction of innovation. In this paper, we compare the different trajectories to the development and uptake of biofuels in Europe, Brazil and the USA. In terms of the timing, direction, and development of biofuels for road transport, the early lead taken by Brazil in sugarcane based ethanol and flex-fuel cars, the USA drive to corn-to-ethanol, and the European domination of biodiesel from rapeseed, manifest significant contrasts at many levels. Adopting a neo-Polanyian 'instituted economic process' approach we argue that the contrasting trajectories exemplify the different modes of politically instituting markets. We analyse the contrasting weight and impact of different drivers in each case (energy security, climate change mitigation, rural economy development, and market opportunity) in the context of diverse initial conditions and resource endowments. We explore the 'politics of markets' that arise from the different modes of instituting markets for ecologically sustainable economic growth, including the role of NGOs, the scientific controversies over land-use change, and the contrasting political institutions in our case studies. We also place our analysis in the historical perspective of other major carbon energy transitions (charcoal to coal, coal to petro-chemicals). In so doing, we explore the idea of the emergence of new modes of governance of contemporary capitalist political economies, and the significance of politically directed innovation.

The research is based on an extensive primary research programme of in-depth interviews with strategic players in each of the geographic regions, qualitative institutional analysis, a scenario workshop, and secondary data analysis.

Keywords/tags:

Biofuels, peak oil, climate change, politically directed innovation, instituted economic process, USA, Brazil, Europe

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1 INTRODUCTION

Capitalist political economies are facing historically unprecedented challenges. Previous major "long wave" transformations, the agricultural and first industrial revolutions, the development of electric power and chemical industries, nuclear energy, and ICT transformations – all shifts in techno-economic paradigms (Freeman and Perez, 1988) – have occurred through expanding and adding to previous resources and technologies. Restricting the focus to energy and materials, the socio-economic utilisation of carbon has undergone successive historical changes, by discovery and exploitation of new resources: from wood, charcoal and peat to coal[1] as a source of energy and chemicals, and from coal to the petro-chemical technological platform that established itself after the Second World War. Now, capitalism for the first time faces a drive to technological change arising from resource depletion: the threat of 'peak oil', and the declining availability at economic and political costs of a major primary source of energy and materials (IEA, 2008; Aleklett et al. 2009; Hirsch et al. 2005).

Secondly, although historical capitalism has faced successive and significant challenges of pollution – lead in air and water threatening human health, CFCs creating the hole in the ozone layer, chemical pesticides (DDT), and so on – the scale and generality of the economic and ecological threat of Global Climate Change (GCC) are quite unprecedented, and present major challenges to the political direction and governance of capitalist economies. The significance of Stern (2007) is that it points to how current patterns of economic activity threatens continuation of those economic activities – quite apart from effects on human health, the ecology or the stability of the climatic system.

Thirdly, there is of course a connection between these two unprecedented challenges: if climatic and geological history of the planet had been quite marginally different, peak oil or coal could have already have occurred decades ago, or be in the long distant future. In either case, the challenge of anthropogenic climate change would have coincided quite differently with the history of capitalist economic growth. We are where we are through a contingent alignment of geological and historical time. And, fourthly and finally, routes out of fossil carbon dependency for energy and materials, themselves have considerable consequences for, and effects on, anthropogenic GHG, especially with increased competition for the use of land for increased food demand, as well as for biomass for non-food use – especially energy and materials. Production of food and agricultural uses of land are more significant emitters of GHG than total global transport (World Resources Institute, 2005; IPCC, 2009, Figure 2.1).

Unprecedented circumstances may or may not drive unprecedented transformations in the political economies of capitalism.[2] We attempt here to argue a case for considering the current shift in techno-economic paradigm as qualitatively different from previous ones, especially in terms of the pro-active and strategic role of states and international organisations in driving and shaping change. Failure of political direction at a national, regional or global level – the continuation of capitalism as usual – may jeopardise both the economic future of capitalism and the ecological sustainability of the planet. This argument is a complex one, and we need to pay close attention to some significant historical precedents, and will do so briefly below.

We develop the argument using the example of biofuels as liquid transport energy. The technological systems of fuels and vehicles (terrestrial and avian) have transformed the socio-

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[1] It can be argued that there was an emerging crisis of resource depletion in the use of wood and charcoal prior to the major shift towards the adoption of coal in the 17th and early 18th centuries (Thomas, 1986; Nef, 1932). But there is also much evidence that the availability of cheap coal in Britain created unique resource conditions in that country which *partially* explain why the industrial revolution started there (Allen, 2009). Charcoal and peat were relatively more abundant in those nascent industrial economies in continental Europe.

[2] We are reminded of the argument developed by Jared Diamond when considering socio-political-economies that have either survived or failed to meet resource depletion or climate change challenges, and his insistence on political and cultural adaptability (Diamond, 2005) Resilience theory has also made a significant contribution to this discussion (see Costanza et al., 2007; Gunderson and Holling, 2002; Millenium Ecosystem Assessment, 2006). The notion of technology lock-in developed by David (1985) has been elaborated by Unruh (2000) to describe a more macro-scale techno-institutional complex reproducing carbon lock-in to a fossil fuel political economy. This approach also points to the systemic resistance that would be expected to place constraints on the creation of technological and institutional experiments for escaping carbon lock-in.

economic world since the beginning of the 20th century, with both the major components involved in interdependent changes. Small unit passenger vehicles (cars and motor bicycles) or HGVs (lorries, tractors, etc.) have experimented from the beginning with a variety of engines and fuels, electricity, ethanol, steam, petrol, diesel, with oil becoming the dominant design from early in the twentieth century to the present day. Liquid fuels are currently the only future alternative for air travel, but we believe that they will also continue to be a dominant technology for terrestrial vehicles for decades to come, especially in developing economies and for interurban, long distance travel. Hybrid electric-liquid fuel vehicles may play a significant role in this mix. The question is then whether liquid fuel will be derived from fossilised or renewable biomass. And the consequential question is whether the outcome will effectively meet the twin challenges of GHG reduction and economic sustainability or growth in the face of fossil resource depletion, and competition for land for increased and multiple demands. Whatever new balances might be struck between alternative transport systems, the flexibility of road transport vehicles and the historic investment in their infrastructures, in our view, make the vision of a world 'after the car' (Dennis and Urry, 2009; Urry, 2009), 'after the tractor' or 'after the lorry' premature, even restrictive.

2 INNOVATION AND THE STATE: THEORY AND HISTORICAL EXAMPLE

In this paper, we will be exploring three contrasting examples of politically directed pathways to biofuels in Europe, Brazil and the USA. In a sense, they can be seen as evidence of experimentation with new forms of political direction of innovation and techno-economic paradigm shift. In ways we shall explore below, they manifest some shared and novel political instruments, but also significant new variety creation in 'politico-economic technologies'. They vary markedly in both innovation direction and political objectives in facing global challenges, representing embryonic examples of experimentation with novel forms of political direction of capitalist economies. We will be developing the 'instituted economic process' (IEP) approach to suggest a new historical turn in the relation between polity and economy in the innovation process. In particular, we will suggest that market-led innovation, where the dynamic of variation and selection is primarily located in firms and markets, is being supplemented by long-term, politically driven, innovation where new state political strategies and technologies are emerging in the face of unprecedented historical circumstances. There are new modes of politically instituting market economies, in this case, of transport energy. In making this bold claim, however, we need first to review both some of the literature of major historical technology transitions, and some major historical examples of state-driven innovation.

There are two sides to the argument that we are entering a new historical phase for the role of the state in innovation. On the one hand, we suggest that there has been a long-standing theoretical underestimation of the role of states in shaping and driving innovation in both market and non-market economic modes.[3] On the other, and connectedly, there are many significant historical examples of where states have intervened, often very forcefully, constituting the major catalysts of socio-technical change. So, in this respect we need to show how, and to what extent, current modes of politico-economic change are already different from previous ones, and in ways that appear to be developing, specifically to meet current challenges.

Firstly, then, as a broad generalisation, in the Marxist and Schumpeterian views of major technological change, the historical waves of creative-destruction have primarily been driven by market actors in a market environment, in order to generate 'rents' from competitive advantage gained by innovation. Strikingly, within this tradition Freeman and Perez's 1988 view of techno-economic paradigm shift is driven by market gains on input and output costs,[4] to which the socio-political infrastructures reaccommodate and adjust.[5] The model is almost

[3] For an interesting historical perspective on the role of the state in economic thought, particularly in relation to innovation, see Reinert, 1999.

[4] New techno-economic paradigms involve 'the system's response to *major* changes in the price of *new* inputs, and *new* technologies which exploit their potential to reduce costs of both labour and capital, as a result of new total factor input combinations and organisational-managerial innovations.' 58

[5] 'It [paradigm change] shows the need for a full-scale re-accommodation of social behaviour and institutions to suit

one of where technologies and markets lead, states must follow. The engine of change lies within 'the economy'.

The National Systems of Innovation (NSI) literature accords the state and politics a much more prominent role in shaping and promoting innovation (Nelson and Rosenberg, 1993; Nelson, 1990; Lundvall et al. 2002; Freeman, 1987). A feature of the NSI approach, almost by definition, is that different political and state roles are analysed for the shaping of innovation and major technological change in countries such as Japan, Denmark and the USA. Nonetheless, overall a common feature of this analysis is the significance attached to the supporting role of the state for market-led, entrepreneurial innovation, whether in terms of providing the necessary public science base,[6] creating facilitatory legal and contractual frameworks, and fostering technological learning between firms. There are different institutional environments, more or less supportive, shaping the patterns of innovation, the driving source of which remains primarily located within the market. That is where the 'engine of progress' is seated: the Marx-Schumpeter driving force placed in a conditioning and sustaining environment.[7] As with the varieties of capitalism approach, the emphasis on the effects of different political systems, and different articulations of national systems with the global economy, is one that informs our analysis, conditioning the novel responses to novel challenges which we seek to analyse. We will aim to extend this analysis by suggesting that when circumstances alter, requiring significant and long-term strategic direction to change, the driving force of innovation, *to a certain extent and in some parts of the economy*, shifts location from the market to the state.

Over the past two or three decades, the ecological impacts of economic activity have become increasingly prominent, and perhaps sufficiently so, to count as such a change in circumstances. Where innovation (or sociotechnical) system ideas have been applied to the challenges of sustainable development, the principal focus has been on the role of government policy in supporting and protecting niches of novel sociotechnical innovations that might eventually challenge the dominant regime (for example, Rip and Kemp, 1988; Rotmans et al, 2001; Geels, 2002). But this approach still views the principal dynamic of system transition to be one based on market competition, with government intervening at the edges to modify the rules of the market game; the key system-builders remain private actors. More recent contributions (Smith et al, 2005) have criticised the bottom-up approach, suggesting that there have been significant historical examples of system transition that have been steered by a much greater degree of longer term planning and explicit coordination by alternative governance regimes. In our view this correctly raises the possibility that, in some cases, governments (interacting with other actors within the governance regime) will be the driving force for system transition.

Following this, we will be reflecting on emerging evidence that sustainability challenges such as climate change and peak oil appear to be drawing a more directed and significant intervention from governments, albeit to different extents in different regions. To describe our interest in the language of the multilevel transitions perspective, we are looking at possible changes to the landscape, a move away from the dominant neoliberal political economy of the post war period. But, as yet, the concept of the landscape is not sufficiently fleshed out to easily accommodate this question.

However, we also suggested that these literatures underestimate major historical examples of the directive role of the state in innovation, where political strategy has been the central catalyst to socio-technical change[8]. And we will then argue that even with respect to these

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the requirements and the potential of a shift which has already taken place to a considerable extent in some areas of the techno-economic sphere. This reaccommodation occurs as a result of a process of political search, experimentation and adaptation [not conflict], but when it has been achieved, by a variety of social and political changes at the national and international level, the result good "match" facilitates the upswing phase of the long wave.' 59

[6] 'Universities are an important part of the modern capitalist engine. They are a recognised repository [sic] of public scientific and technological knowledge. They draw on it in their teaching. They add to it through their research.' (Nelson, 1990, 206).

[7] 'Over the years we have learned to do many things to make the original engine run more efficiently, with more power and less waste, and have learned to steer it at least broadly. We share knowledge, and coordinate action in certain situations. Public funding and government leadership have been used to make generic knowledge more readily public, and to guide and spur the system when this has seemed appropriate.' (Nelson, 1990, 212)

[8] The historical examples of widespread nationalisation – socialisation of the 'commanding heights' of the economy –

examples, the world has changed. This is obviously not the place for extended analysis, but the types of examples we can point to are first, military command economies (and, to a lesser extent, military driven innovation); [9] second, major infrastructures of utilities, transport and communication; third, health provision and medical innovation; [10] and fourth, food security and 'green revolutions'. [11]

Of course, there are a number well known historical examples of political strategy being the central catalyst for socio-technical change. The most relevant and testing example for our analysis can be taken from those sudden wartime episodes of 'resource depletion' that stimulated military command economies in Germany, the US and elsewhere to induce technological and industrial transformation whose consequences and achievements continued long into peacetime, and the relaxation of military command. Two major energy and materials transitions can be identified, one from the First World War the other from the Second. In the First World War both the USA and Germany were faced with a major disruption of the supply of nitrogen from Chilean guano. It is difficult to fight wars without nitrogen to make explosives, and nitrogen had already become a core resource for agricultural productivity, more acutely necessary to feed populations in times of wartime restrictions on international trade. As Hughes (1983) demonstrated,[12] the production of nitrogen from atmospheric gases, using industrial chemistry, required enormously increased demands for electric power. In the USA and even more in Germany, this led to military command political strategies for transforming and scaling-up electric power generation and transmission networks, especially the formation of regional grids. The experience of war, he argued, was an inspiration to postwar 'planned systems', where coordination between market and public actors, integration and standardisation of smaller scale economies of electrical energy, was required.

An even more apposite case relates to the emergence of the petro-chemical technological platform that came to dominate the market economies of the second half of the 20th century. Contrary to the macho-entrepreneurial symbolic weight of oil in capitalist mythology, military command economies were critical in the transformation process. Again key energy and material resources were dramatically curtailed: in the run up to the Second World War, Germany lost access to both oil and rubber, the USA had plentiful resources of oil, but was suddenly cut off from supplies of rubber from Malaysia and the Far East. Under Nazi dictatorship, the German chemical industry was driven to develop alternative liquid fuels and synthetic rubber (the future building blocks of plastics) from coal. The consequence was a period of intense and pressured innovation, resulting in key developments in catalysis and refinery (Spitz, 1988). The production of syngas and liquid fuels from coal for aviation and terrestrial transport, fractionating refinery outputs, were amongst the major advances. In the USA, under a military command economy, the government engaged in industrial reconstruction, pushing together the chemical and petrol refinery industries, in order to develop the polymers to produce synthetic alternatives to rubber (Mowery and Rosenberg, 1998; Spitz, 1988).[13] Extreme as circumstances and political regimes were, key innovations in

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could also have been included in this analysis, with state control over gas, steel, coal, railways, roadhaulage, car manufacturing, telecommunications, all included in the UK experience. The subsequent privatisations have also entailed states constructing and shaping the industrial architecture and markets, including the innovation environment. Our focus, however, is to emphasise the role of the state even in those historical conditions that are not claiming to challenge the foundations of capitalist political economies.

[9] Major contributions with respect to military-inspired innovation are provided by Noble, computerised design and aircraft innovation (Noble, 1986), and McKenzie (1996), again on computerisation in relation to control systems. Another is the www. See also Ruttan, 2005.

[10] Mokyr, 1998.

[11] Conway, 1997; Evenson and Gollin, 2003.

[12] In addition to the significance of military command economies for politically driven innovation, Hughes provides important examples of the varieties of political shaping of innovation of earlier electrification in his comparison of Chicago (market led), Berlin (political and market synergy) and London (political obstruction followed by political leadership of innovation).

[13] Spitz (1988) gave a much more detailed and insiders view of the formation of the petro-chemical technology platform, but also a much more trenchant account of the role of political direction in both the USA and Germany. Mowery and Rosenberg (1998), heavily reliant on this source, fail to extract the full significance of the political shaping of paths of innovation. Wartime is almost reduced to a temporary passage, so not requiring its lessons to be integrated into an analytical framework: 'The Second World War thus transformed the rubber industry from one that depended on nature for its primary raw material to an industry that depended on new chemical processing technology for its primary inputs. The wartime experience of this industry is a compelling illustration of the ability of a technologically

refinery, industrial chemistry, and the reorganisation of industry, were driven by political and military command. They laid the foundations for the post-war petro-chemical world that we have since become accustomed to and dependent upon – even to the extent that the US petrol and chemical industries looted[14] the German chemical industry for key technologies advanced under dictatorship and wartime command (Spitz, 1988). This techno-economic paradigm shift was clearly driven by the twin exigencies of abrupt and extreme resource reduction and the objectives of war. So, our challenge to making a case for the novelty of current politically driven innovation for renewable and ecologically sustainable energy is to draw both parallels and differences with these more abrupt and temporary circumstances of resource crises created by the First and Second World Wars.

Aside from electrification, many examples could be adduced to illustrate the significance of variably politically driven innovation in infrastructures, so only a brief example related to vehicular transport is worth highlighting here: the construction of the US Interstate Highway System. Interestingly, the USA road network was developed exclusively within the capitalist political economy epoch, without the legacy of previous national road network systems – even dating back to the Romans. If the car is iconic of individualist consumer market capitalism, it has run on roads developed as public goods, built by private contractors, but as exemplary of non-market socio-technological innovation system. There are strong arguments, especially following the construction of the autobahn network in Germany, that public road design drove car design and technology innovation (aerodynamics, tyres, engine performance, chassis), as much as vice versa (Flink, 1988). The US Interstate Highway System developed over a long period, often political battleground, between federal, state, and market interests – and was significantly driven by consumers, and organised consumer demand for higher quality roads (Lewis, 1997).[15] Ultimately, however, and partially reflecting wartime experiences and defence objectives, a pro-market cold war Republican President, Eisenhower, legislated for and funded the creation of the renowned Interstate Highway System, nationally integrated, standardised, and regulated, coast to coast, North to South.[16] The result transformed not only deep rural isolation[17] but urban and suburban design with its novel public infrastructure for private mobility. The Interstate System abandoned pre-war experimentation with private tolls, and became more not less public with the expansion of car mobility (Flink, 1970; McNichol, 2006). The state thus played a critical role in US national economic market integration, and the creation of new economic activity multi-level scales, in the process. The *interdependence* between non-market and market economies manifest in the Interstate Road System exemplifies the multi-modal growth dynamic of capitalist political economies: roads fit for cars and trucks, trucks and cars fit for roads. This growth dynamic was fuelled by the virtuous circle, across market and state governed economic activity, which connected greater use of roads to increased revenue from road taxation to investment in expanding the road network, which stimulated further demand, thereby initiating the cycle again.

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dynamic economy such as the United States to overcome natural resource constraints' !!! (op. cit. 91-2).

[14] Appropriated technology by the victor's *force majeur*, rather than normal market modes of acquisition.

[15] As an example of consumer-driven innovation but non-market provision, the creation of roads fit for bicycles, first mobilised by the League of American Wheelmen in the 1890s and subsequently taken forward by automobile consumer groups, provides an interesting historical bi-line (Flink, 1970).

[16] The Federal-Aid Highway Act, 1956 financed the construction of 41,000 miles of new roadway through the Highway Trust Fund, which was based on hypothecated petrol, diesel, and tyre taxation, after many alternatives had failed. This peculiar state financing has been described as 'a virtual Möbius strip of money: the more cars travelled, the more gas they consumed; the more gas meant more momey to build more miles of highways; which allowed more cars to travel more miles and consume more gas.' (Lewis, 1997, 127). As an engineering feature, it rivals the Great Wall of China as the most visible human construction to be seen from space, as 'the largest engineering project in history'. Ironically, the architect in the Senate of the Bill that financed the Interstates was none other than Albert Gore Snr, making him indirectly responsible for one of the largest carbon footprints in history – a legacy now addressed by his son.

[17] One of the key economic aspects of road infrastructure development was to continuously connect rural communities and homesteads to the wider world, as was clear from the interwar programmes developed by Thomas McDonald at the Bureau of Public Roads, the legendary figure of American road mythology. Remarkably, before the *post*-Second World War road development, many parts of the US were cut off from each other, often for months at a time, because of inaccessible mud tracks.

3 UNPRECEDENTED HISTORICAL CHALLENGES

In considering the parallels and differences between the politically driven innovation of transport energy today and these historical examples related to abrupt but temporary resource depletion or economic scale integration requiring national standardisation and regulation, we suggest that global climate change and peak oil represent circumstances that are unparalleled in scale and nature, and that only politically driven, long-term and strategic innovation offers any possibility of overcoming limits to growth, whether for food, energy or materials. Markets, including futures markets, do not operate on the time-scales or provide the incentives sufficient or relevant to bring about this transformation. The oil shocks can be seen as a prelude or harbinger of progressive depletion of finite resources, and in that respect point to parallels with previous military command economies – and the first stages of our Brazilian example will bring this to the fore. But they were temporary, and at the extreme end of politically manufactured resource constraints. As is already clear from OPEC political strategies at Copenhagen, the use and availability of fossil fuel to 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). 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 et al. 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 petro-chemical depletion – and many have argued that even with strong market signals, economic and political actors have largely been in denial (Legget, 2005). A glance at Figure 1 below demonstrates the powerful market signals of oil market price, that, even granted the academic consensus on the negative relationship between oil price rises and GDP growth (Jones, 2004), have failed to induce any strategic response by market actors to shift away from oil dependency. Perhaps, the long period of price stability induced narcosis, only interrupted by the occasional nightmares of oil price spikes – until one regards the steady upward trend from 1998, and especially the current bounce back to 1979 levels *even in a period of global recession*.

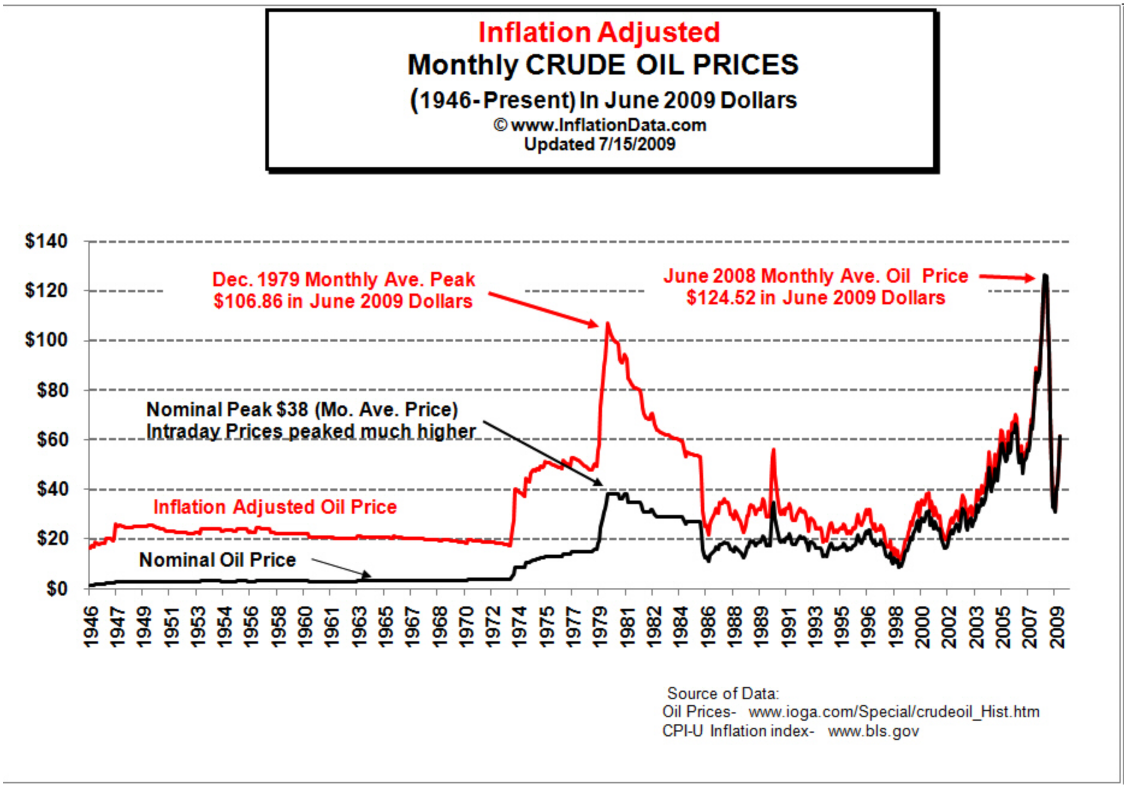


Figure 1: Oil prices, nominal and inflation adjusted, 1946-2009. Source www.bis.gov

Likewise with the economic costs of global climate change, the central implication of the analysis developed by Stern (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 to sustainability. When it comes to finding a substitute for something as fundamental to the economy as oil, only scientifically informed, politically-led and long term strategic innovation – as well as regulation – offers capitalist political economies a possible route to sustainable economic growth. There is, of course, a question mark, to which we shall return, as to whether, at a national, regional, or international level, such concerted political direction will emerge to face these combined challenges. This, then, is the novelty of circumstance that requires novelty of political management of economies. Our empirical studies explore the manner and extent of varied responses.

4 POLITICALLY INSTITUTED MARKET ECONOMIES OF ENERGY

The theoretical approach advanced here is an 'instituted economic process' approach, which we believe is useful because it allows us to explore varieties of modes of instituting economies. Arguing for a concept of a dynamic and variable multi-modality of capitalist economies, the framework avoids dualisms of state (planning) versus market (spontaneously emergent, universalistic). From previous work, we take as our starting point that market economies are as instituted, historically and socially, as non-market, public economies (Harvey, Quilley and Beynon, 2002; Harvey, Ramlogan and Randles; Harvey, 2010, forthcoming). Thus, for example, the supermarket system of food provisioning, distribution, exchange and consumption within the UK is an historically instituted and evolving system, markedly different from the instituted food economies of the USA or continental European countries – and markedly different from UK food provisioning of just two or three decades ago. Likewise, we have attempted to show how novel public economies of knowledge, new forms of public 'commons', involving knowledge production, distribution, appropriation and use, have become instituted during the on-going revolution in the biological sciences and technologies (Harvey and McMeekin, 2007). These have been seen as the outcome of processes of differentiation and interdependence between public and private modes of economic organisation.

The key development of this approach which we aim to address here concerns the complex interaction between economic and political modes of instituting economic processes, and in this case, for economies of transport energy whose distribution and exchange are organised in markets. So here we are exploring politically directed market innovation, in contrast both to market-led innovation and innovation by state enterprises in previous historical periods. On the one side, there are the political 'technologies' of directing innovation, a wide range of instruments, objectives, and strategic visions. On the other, there are varieties of emergent economic organisation of production, distribution and exchange, often with new classes of economic agent, but significantly with new industrial divisions of labour, horizontal and vertical. For example, agribusiness has emerged as a significant new component in many of the new divisions of labour, with sugar companies now providing energy for cars as well as calories for humans! The interaction between political direction and emergent economic organisation is complex in the sense that pre-existing economic organisation often conditions political direction, on the one hand, and on the other, political direction may not directly plan or coordinate the organisation of market actors, except, notably, in the case of nationalised entities. In some cases, political direction is limited to an orientation to something as general as 'renewable energy', without determining who might provide what renewable energy, or in what mix. In others, the political direction can be much more prescriptive – a mandated target of x% of biofuel to be blended with a fossil fuel. But here too, the political direction falls well short of picking specific technological winners, let alone the shape of the industry providing the mandated commercial product. So, in comparing the sharply contrasting trajectories of transition in Brazil, the USA and Europe, we will be analysing the outcomes of complex interactions, resulting in a variety of forms of politically instituted economies of transport energy, and forms of emergent economic organisation that occurred as a consequence of governmentally oriented innovation. The term 'politically instituted' thus covers the full range of possibilities from fully planned economies to light touch steerage and orientation. The advantage of the IEP approach is precisely that it concerns itself with this variation and interaction of modes of instituting economic processes.

When considering the political technologies of directing innovation, we will be exploring a wide range of instruments affecting both supply and demand side with policies impacting on: the science base; the innovation process, through to commercialisation; the demand side in fuel markets; the coordination of the fuel-vehicle system; innovation to meet sustainability regulation; and international trade. Given that one of the central framing conditions involves resource depletion, one of the key and variable determinants of political strategy concerns the resource endowments of the different regions, whether in terms of fossil fuels, or in terms of comparative advantage of biomass, between sub-tropical and temperate zones, for example. These preconditions become more significant the more there is reliance on bioeconomy alternatives to fossil carbon. It might be thought that regional vulnerability to impacts of climate change – frequency and severity of extreme events such as hurricanes, for example – might similarly act as determining conditions for political orientation. But we shall see that Europe, perhaps the least immediately vulnerable region, stands out for shaping its orientation by concerns of sustainability and climate change mitigation. So, we look elsewhere in the political culture to account for this variation.

In this section, the current politico-economic challenges to sustainable economic growth have been put in theoretical and empirical context, in order to understand the parallels and differences in the transition to renewable and sustainable energy, in particular with respect to terrestrial and aviation transport. In the next section, we turn to our empirical comparative analysis of three contrasting transition pathways. A thumbnail summary of the contrasts highlights the issues at stake:

Brazil: the initial establishment of a major political programme of replacing dependency on fossil fuel with bioethanol from sugarcane was a response to the two oil shocks of the 1970s, so pointing to parallels with earlier abrupt and temporary resource depletions. Yet the continuity of the development into the present era both changed the context and the drive behind the continued expansion, notably with the development of a transport fleet of Flex-Fuel Vehicles (FFVs).

USA: after a brief episode of a drive to bioethanol following the oil shocks, and the USA's own national 'peak oil' in 1972 (Defeyes, 2001), the USA's political drive to energy security and independence has been based on bioethanol derived from home grown maize, and a subsequent major programme to shift towards ligno-cellulosic bioethanol.

'Europe': although there is much diversity between European nations, a pan-European framework for renewable energy has focused predominantly on greenhouse gas mitigation, this being achieved in the main through renewable biodiesel derived from domestic rapeseed, supplemented by imported bioethanol, and some bioethanol derived from domestic sugarbeet and wheat.

Thus, the three regions are contrasting in political objectives, in biomass resources, and in fuel-vehicle systems. In this analysis, we will be necessarily schematic, focusing particularly on the aspects of politically driven innovation, the processes of politically instituting biofuel economies of energy.

5 THREE DEVELOPING ECONOMIES OF ENERGY: BRAZIL, THE USA, AND EUROPE

5.1 Brazil

Brazil currently enjoys the highest levels of consumption of renewable transport fuels in the world (at approximately 40%), using bioethanol from sugarcane, generally regarded to be the most beneficial for mitigating greenhouse gas emissions of all current technologies (Goldemberg and Guardabassi, 2008; Zuurbier and van de Vooren, 2008; Smeets et al 2008; Brehmer and Sanders, 2009: Macedo and Noguiera, 2005; Macedo et al. 2005). There has, however, been a long and winding developmental path – with some sharp turns, but one that has been characterised by a markedly directive state for most of the last 80 years. The sugarcane and sugar producing sector exemplified this pre-history of Brazilian biofuels, with the Istituto de Azucar e Alcool (IAA) established in 1933 by President Vargas, imposing an integrated market price, price stability, production quotas for different regions, and centralised distribution and a monopoly exporter (Johnson, 1983; Nurnberg, 1986). This policy was motivated by a development strategy, particular in circumstances of high volatility of world commodity prices.

Under the dictatorship of the Generals (1964-85), 'state entrepreneurship' became a major development strategy, notably with the formation of Petrobras, the national petroleum company, and its affiliated petrochemical industrial base (Evans, 1979, 1982). When confronted with the 1973 and 1979 oil shocks, although initially resistant, Petrobras was to become a central strategic instrument for the substitution of imported petrol by home grown bioethanol from sugarcane. The pre-existing concentration and centralisation of the sugarcane industry under the IAA dovetailed with this strategy, partly as it coincided with yet another global collapse in sugar prices.[18] The two phases of the strategy, established under legal decrees, responded in turn to each of the oil price shocks, ProAlcool and ProAlcool II in 1975 and 1979 respectively, described as a 'politicised market economy' for energy (Barzelay, 1986). What makes this first phase of Brazilian bioethanol strategy distinctive was the combination of development with energy security objectives in response to sudden, if temporary, 'resource depletion'. The savings in oil imports alone resulting from bioethanol substitution, even following Brazil's own oilfield discoveries and exploitation, amounted *annually* to between US$500 million and US£1 billion, in the 1980s and 1990s, totalling $69 billion in saved imports for the duration of the programme (De Almeida et al. 2007). In many ways, this placed Brazil in a uniquely advantageous position, exploiting its distinctive resources, including the high conversion potential of solar energy into biomass in the sub-tropics (Mathews, 2007).

As suggested, the ProAlcool strategy is marked by two phases, each entailing novel political instruments within a broad orientation (Lehtonen, 2007; Puppim de Oliveira, 2002; Rosillo-Calle and Cortez, 1998). In the first phase, there was a mandated uptake of 20% anhydrous ethanol, which could be blended with petrol without requiring vehicle engine modification. Petrobras was mandated to purchase the bioethanol from state subsidised biorefineries at a fixed price. The IAA was funded to develop a national agricultural research programme to develop new varieties of sugarcane, to optimise sugar content for bioethanol conversion. Petrobras, already monopoly distributor of petrol, extended its role as blender and distributor of the fuel.

The response to the second oil shock was to move to a much more radical phase, this time including a transition to new vehicles, so entailing a fuel-vehicle technology system. Engines developed by the state controlled Centro Tecnologia Aeronautica to run on 100% hydrous ethanol were manufactured, by negotiated agreement and government signed contracts with the major global car manufacturers (Fiat, VW, Mercedes Benz, GM and Toyota) (Goldemberg, 2008). In fact, manufacturers saw this as a market opportunity – albeit politically constructed – and actively sought and promoted the development of an ethanol car fleet (Barzelay, 1986), producing 250,000 cars by 1980, 350,000 by 1982. Using procurement as an instrument, all state cars were obliged to be 100% ethanol, and subsidies were given on vehicle prices. By the early 1980s, 80% of all new vehicles sold were ethanol-only.

The period of military dictatorship manifested strong and authoritarian political direction – symbolised by the effective imposition of the 100% ethanol car – but nonetheless entailed the emergence of new markets, with both indigenous and foreign capital and market players: the 'tripod' (*tri-pé*) policy of development based on a combination of multinational, national and local enterprises under state tutelage (Evans, 1979, 1982). The fall of the dictatorship, and the establishment of a democratic political regime, saw the dismantlement of some, but by no means all, of this political legacy. The ethanol blending mandate remained, and the pure-ethanol car effectively disappeared. Fuel prices were de-regulated between 1997 and 1999, and under the Washington consensus, the Cardoso government pursued a policy of stimulating

[18] The difference in political regimes and correlative industrial organisation, as well as rural class and property structures, might explain why Brazil, rather than India, was able to develop its sugarcane industry into a major producer of bioethanol following the oil price shocks. As a consequence, India lost its premier world position as a sugar producer, and was significantly outstripped by Brazil.

FDI. The IAA was abolished in 1990, but with the result that the primary sugarcane producing region in South Central Brazil effectively eliminated the previously cross-subsidised North East region, which had always been marginal to ethanol production. Petrobras remained a dominant player, if less of a direct agent of government policy. Oil prices returned to their pre-shock levels – until the progressive rise in the late 1990s, but the relative end price of ethanol to consumers remained below 60% that of petrol for most of the first decade of this century, only briefly going above 70% twice (De Almeida et al., 2008).

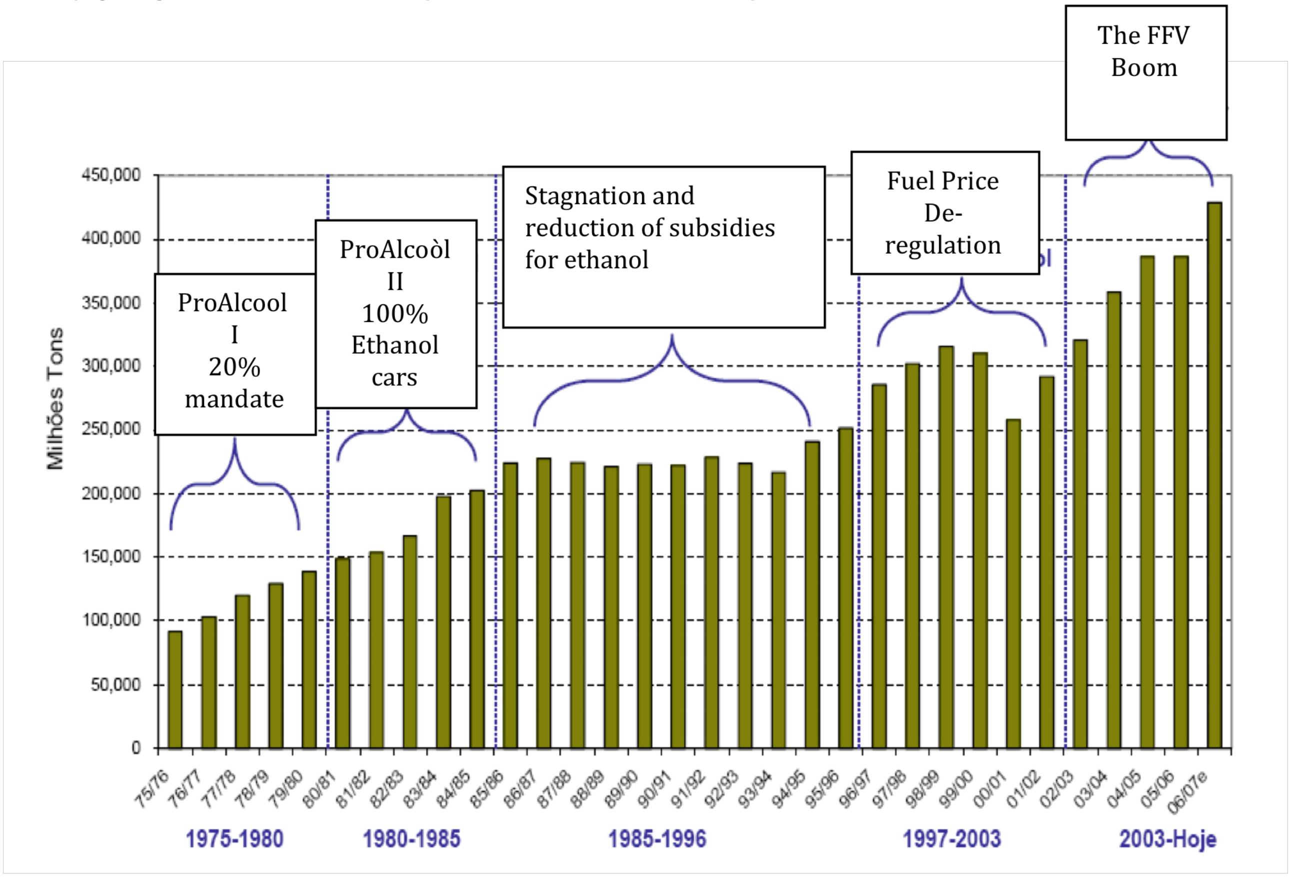


Figure 2: Development of the Brazilian ethanol sector, millions of tons of processed Sugarcane. Source, Romanelli, 2007

So, in spite of liberalisation of the economy, the period from 1985-1997 was one of stagnation at the peak levels achieved under the ProAlcool programme. And, at this point, it is worth emphasising this renewable technology platform that had been created under dictatorship had no ecological imperative behind it – a politically anachronistic perspective at that time – and so achieved major ecological benefits accidentally.[19] Following a period of volatility in the late 1990s, a new surge in bioethanol production occurred, with the evolution of both new political orientation and new political 'technologies'. The development pathway continued to play a significant role throughout, with the biofuel industry a significant sector, employing 700,000 directly, and a further 200,000 indirectly – 100 times more jobs per unit of energy than the oil industry (De Almeida et al. 2007). But, especially after Brazil's major oil discoveries in the Tupi oilfields, the energy security dimension diminished in significance compared with the growth of the global export market. During this period, Brazil became the premier exporter of world bioethanol. Nonetheless, given the price trend of fossil fuels, bioethanol has been becoming more competitive, especially in the domestic market, placing Brazil in an enviable advantage in facing global petro-chemical resource depletion.

[19] There was a major concern over pollution, particularly in Sao Paolo, and ethanol cars were seen as ecologically beneficial in reducing urban pollution – but not for greenhouse gas mitigation.

Under President Lula, a range of new political directions to innovation have occurred, although in a very different mode to that under the dictatorship. Petrobras has continued to lead innovation in fuel development, and has been supported by the state in creating the infrastructure for expanding exports. Its R&D facilities at CENPES are closely integrated with the Federal University of Rio de Janeiro. It continues to dominate distribution and orchestrates the development of biofuel supply from major refining companies, such as Dedini, and Copersucar, the sugar producers' federation.

Perhaps the most visible and significant development has been the emergence of the fully flex-fuel vehicle, capable of running on 0-100% of petrol, liquid gas, or bioethanol. Again, the government played a key role in negotiating with car manufacturers for the production of FFVs, guaranteeing subsidies on purchase. As a consequence, already by 2006 80% of new car sales were FFV, presenting the advantage for the consumer of eliminating the risk of relative price shifts between fuels in a period of considerable volatility. The effects of the FFV innovation on domestic market growth of bioethanol production are seen in Figure 2 above. It can now claim to be the most advanced fuel-vehicle technology system in the world.

In terms of the strategic and long term political support for a shift to renewable bioenergy, there has been major funding of both basic scientific research, often co-ordinated with commercial R&D, with a vision of coordinated innovation from crop, cultivation, biorefinery through to multi-product outcomes. FAPESP, the Sao Paolo State research funding body, has supported the development of sugarcane genomics, and the development of transgenic and advanced hybridisation technology sugarcane in the technology cluster near the University of Campinas (notably Allelyx and Canavialis). [20] Dedini has developed world leadership in biorefinery, with advanced operations producing surplus electricity from bagasse, as well as fertiliser from vinasse (previously a pollutant to the water-table). The production of electricity for the grid (bio-electricity) has quadrupled between 1995 and 2005, now yielding 3% of the total electricity supply. Dedini, supported by FAPESP, has been operating a commercial demonstration plant with Copersucar, for ligno-cellulosic bioethanol since 2003, producing 5,000 litres per day. Many of these state-supported research developments have entailed long-term commitments, and would not have occurred, certainly not in such a coordinated manner, as a response to erratic and fragmented market signals.

Finally, Lula initiated a biodiesel programme, which had the joint aims of diminishing Brazilian dependence on imported diesel, developing new technologies and crops, and specifically targeting poverty reduction for small farm holders (Wilkinson and Herrera, 2008). Thus, Petrobras has been assigned the role of guaranteed purchaser in auctions for a variety of crops (jatropha, castor, soy) from small holders especially in the North East. In order to develop this market, again with a long term vision, mandates now dropped for ethanol, are imposed for biodiesel, with a 2% blend required for 2008, rising to 5% in 2013, under the 2005 National Programme for the Production and Use of Biodiesel (De Sousa and Dall'Oglio, 2008; Pousa et al. 2007). Petrobras itself is also taking the opportunity of this politically underwritten market to develop its own technology of producing biodiesel, HBio.

Finally, in the current global context, biofuel production in Brazil has entered firmly into the perspective of greenhouse gas mitigation and biodiversity protection. Whilst leading the world almost by accident in the first instance, it now is promoting sustainability certification of all biofuels, and a zero deforestation policy – although no sugarcane is grown within a 1000 kilometres of the Amazon, and most expansion of sugarcane production has been at the expense of low-intensity pasturage. As Mathews has pointed out, one of the conditions of developing a biofuels futures market, now established in Brazil, has been quality assurance and standardisation, including regulation for sustainability (Mathews, 2008).

Whether under the dictatorship or under the democratic regimes that followed it, there is thus evidence of a strategic political vision for the development of renewable transport fuel, certainly with an economic development agenda, and prompted by resource crises. We have attempted to demonstrate that this vision has evolved, recognising also the significance of major changes in political regime, contrasting authoritarian with democratic political governance of the transition. The 100% ethanol car was a vehicle of dictatorship, whereas the

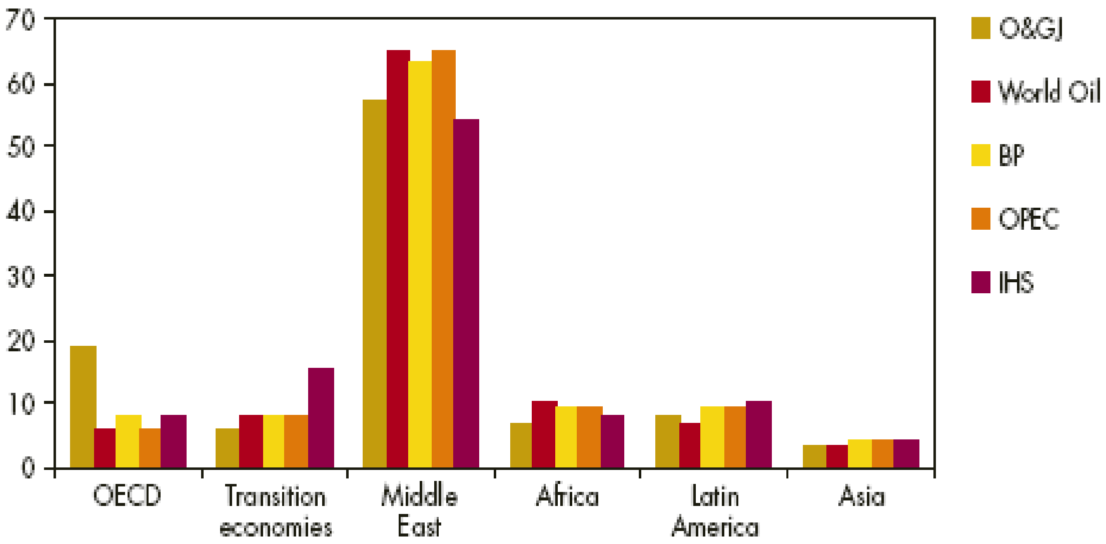
[20] The early initiatives by FAPESP to stimulate Brazilian capabilities in genomic technologies have been described by Harvey and McMeekin (2005).

FFV gave choice of fuel, and lifted risk from the consumer, whilst both ensured the significant expansion of the biofuel industry in their respective periods. Multiple instruments were used, and even if Petrobras as a nationalised industry played a continuously strategic role throughout, its status changed under different political regimes, from a state-enterprise arm of government, to a semi-independent market actor with a large state shareholding. The democratic mode of political governance undoubtedly built on the platform created under dictatorship, demonstrating a continuity in the evolution of strategy. As a consequence, Brazil now represents the country most advanced in the world for developing renewable transport energy, with significant benefits to greenhouse gas mitigation.

5.2 The USA

Any understanding of the political shaping of the USA's shift towards renewable transport fuels needs to start with a distinction between resource security and resource availability: there could be plenty of a given energy resource, but access to it can be secure or insecure; or there could be diminishing energy resources, irrespective of whether there is access or not to it. Insecurity can be relatively temporary. Depletion is permanent. So insecurity may give temporary signals to shift to alternative resources, and then disappear over the political time-horizon. The high cost effects of insecurity and scarcity can be the same, and they can of course interact: insecure access to a diminishing resource. Finally, the political optimum might well be secure access to a plentiful resource: from an oil rich nation once in that position, it could be argued that the USA strives to regain it. For many European nations, this has never been an option: energy self-sufficiency has not been and is unlikely ever to be a realistic possibility. But once the US had past its peak oil in around 1972, the next decades of oil shocks rapidly demonstrated that the security aspect of access to oil was to become increasingly important. Figure 3 below demonstrates just how dependent the USA is on Middle East oil – as the rest of the world had always been, in spite of a brief respite afforded by the North Sea discoveries. Around 60% of the known world oil reserves are concentrated in the Middle East, and 40% travels through the Straits of Hormuz.

Figure 1.10 • Distribution of proven reserves of conventional oil, according to various sources, in percentages



Source: WEO-2004, IEA.

Figure 3: The world distribution of oil resources, as estimated by the IEA, 2004

As with Brazil, therefore, the first major impulse to develop biofuels arose from the temporary signals of the 1973 and 1979 oil shocks, but in the case of the US, without any development dimension, the political response was overwhelmingly a matter of energy security. The first shock prompted the 1974 Solar Energy Research, Develop and Demonstration Act, including a prescient promotion of research for the development of ligno-cellulosic ethanol. The second marked a much more significant push towards the development of home-grown energy to supplement diminishing domestic oil reserves: the 1980 Energy Security Act. As suggested by the title, the political shaping was defined by security, incentivising domestic ethanol producers with excise tax credits and erecting barriers to trade – still existing – to restrict ethanol imports. Research funding of projects for developing biofuels from biomass were put in place, and notably in 1979 President Carter approached ADM, the large agricultural processing company, to switch some biorefineries from producing alcohol to producing ethanol. By the end of the 1980s, ADM was producing 80% of US bioethanol.

But compared with Brazil, the response to the abrupt resource constraints was minor and short-lived, as demonstrated by the Figure 4 below: the significant increase in bioethanol production occurred from the late 1990s, and sharply so only in the first decade of this century.

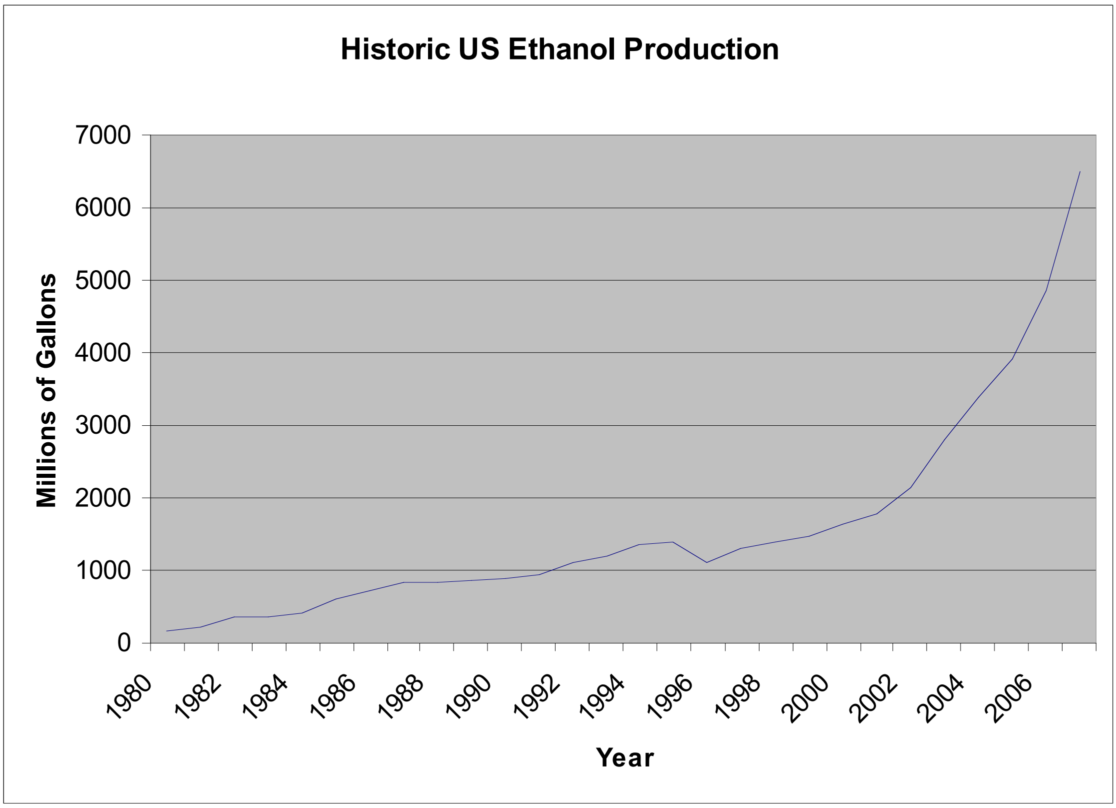


Figure 4: The growth of US bioethanol production

Between 1980 and 2010, the net imports of total US consumption of crude oil had risen from 41% to 66% (IEA, 2006), and the cost of maintaining a military presence in the Middle East exceeded $50 billion in 2002 (The Ethanol Fact Book, 2007, published by the Clean Fuels Development) Moreover, it is striking how the onset of the continuous rise in the price of oil from the late 1990s coincides with the growth trend in US ethanol production. No doubt the bombing of the Twin Towers in September 2001 contributed to the political impetus to improve energy security. Subsequently, a raft of new legislation and novel political instruments shaped the shift towards renewable fuels. In 2000 the Biomass R&D Act initiated a substantial programme of development of new technologies, led by the Department of Energy and the US Department of Agriculture. Increasingly, the funding has promoted ligno-cellulosic bioethanol. Two further major pieces of legislation, the Energy Policy Act of 2005, and the Energy

Independence and Security Act, 2007 (EISA), introduced targets and mandated use of biofuels, initially 7.5 billion gallons by 2012. The legislation combined mandated markets for biofuels with requirements to reduce fossil fuel dependency by use of more energy-efficient vehicles: EISA famously required a reduction in oil use "Twenty in Ten", a 20% reduction of fossil fuels within ten years of enactment. Even more significant for the creation of future markets for biofuels, EISA mandates a steadily increasing volume of biofuel consumption to 2022 (see figure 5). This measure not only guarantees a market for biofuels, but is also technology-forcing, by stipulating the ratio of biofuels from the existing corn-to-ethanol route to those produced by alternative techniques. As figure 5 shows, the volume of biofuels produced from maize is mandated to level off by 2015 at 15 billion gallons per year. This means that the remaining mandated volume, a further 21 billion gallons by 2022, must be sourced from 'advanced' techniques, and the bulk of this should be lignocellulosic ethanol. Furthermore, the advanced fuels must deliver 60% (for lignocellulosic ethanol) or 50% (other advanced biofuel) greenhouse gas emission reductions, compared to a 2005 petroleum benchmark. So, this government measure is both market creating and technology forcing. It sets targets for volume and GHG performance and it specifies, to a large extent, the type of biofuel. But it is not pre-specified technology-forcing either, because the technology to be used to produce the advanced fuels is not pre-picked. So, there is considerable opportunity for experimenting with different technological approaches.

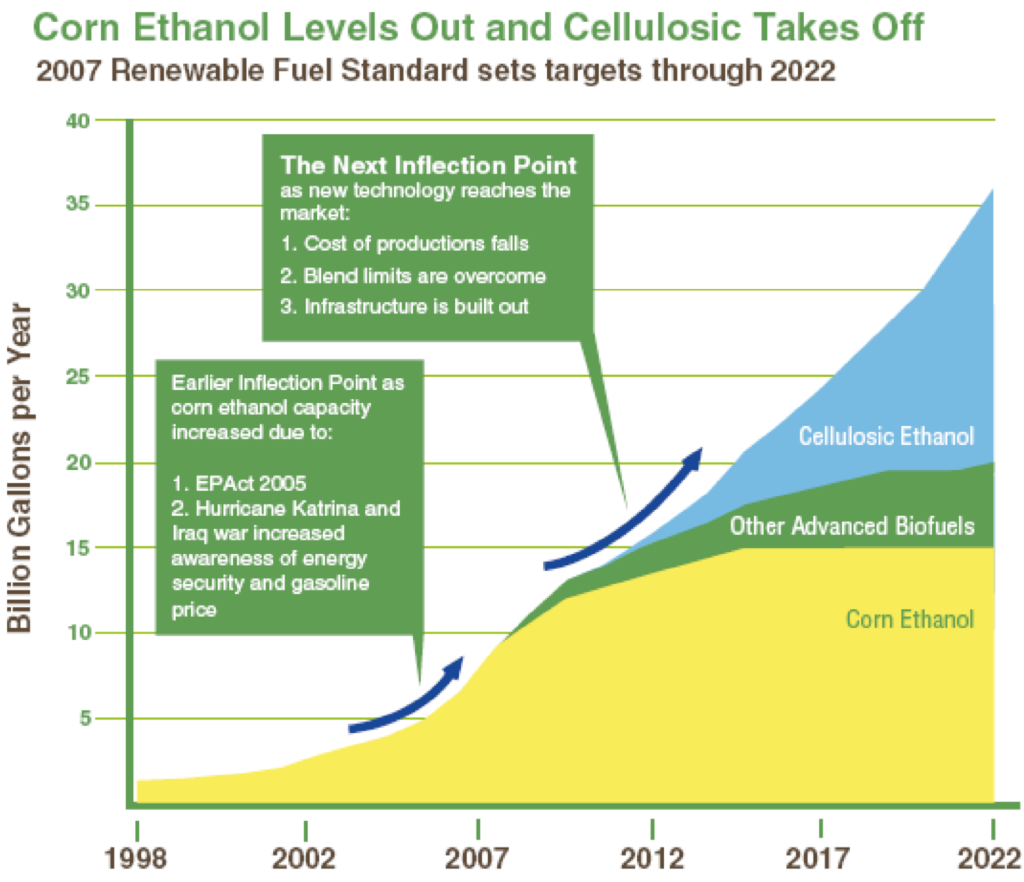


Figure 5: The political regulation of market demand through mandates in the USA

In addition to these radical market political instruments – quite contrary to free market rhetoric of the Bush administration and Republican party – the state has funded a succession of large-scale research programmes, and especially industry-academia collaborations to accelerate the passage from basic science, invention through to innovation and commercialisation. Described by the Secretary of State for Energy as the 'Manhattan Project' of the 21st century, parallels with the wartime directed economies are not so distant. The major difference, however, is that the strategy is now clearly longer term, with timescales of mandates in target stretching decades ahead. Thus the Genomics Systems Biology Program has been dedicated to addressing all phases of development, from development of biomass, modification of characteristics of plant cells, enzymatic catalysts for biorefinery, to new biofuels. The alliance between ADM and Purdue University in developing conversion of ligno-cellulosic biomass to bioethanol using yeast, or the establishment of the Energy Bioscience Institute (EBI) comprising the Universities of Illinois, Urbana Champaign and the Lawrence Berkeley National Laboratory with BP, itself contributing $500 million (Blaschek, 2009), are exemplary of political shaping of the new bioenergy economy.

As figure 6 shows, government investment into biofuels related research and development exceeds $1billion in range of programmes that go significantly beyond funding potentially relevant university research. The two biorefinery initiatives, based on a grant and loan guarantee scheme, are intended to promote the nascent cellulosic ethanol industry by providing the necessary capital to take promising prototype technologies to commercial scale. It is striking, in relation to this, that the guaranteed market has not been deemed sufficient to provide incentives for private capital to support these initiatives. In this ambitious policy, government also needs to fund the development and scaling up of supply capabilities too.

These policy measures have helped to consolidate the emergence of a new class of economic agent within and across the agribusiness and energy industrial division of labour. A relatively small number of new firms have emerged to exploit a particular technology platform for the production of cellulosic ethanol. They compete with each other on the basis of their respective technological visions and their ability to secure investment from public and private actors.

Federal Funding Committed for Cellulosic Biofuels, 2007-Present [million $]

Announced Programs and Solicitations:		Amount	Period
Integrated Cellulosic Biorefineries	Feb 2007	$385	4yrs
Ethanologen Projects	Mar 2007	$23.3	4yrs
BioEnergy Research Centers *	Jun 2007	$375	5yrs
Thermochemical Solicitation	Dec 2007	$9.7	3yrs
Small Scale Cellulosic Biorefineries	Jan /Apr 2008	$200.3	4yrs
Enzyme Systems Solicitation	Feb 2008	$33.8	4yrs
Open Solicitations:			
Biomass Pyrolysis Research	Due May 2008	$7.0	2yrs
University Research	Due Jun 2008	$4.0	1yr
TOTAL		$1,038.1	

* *Funded by DOE Office of Science*
Note: Actual funds deployed will depend on successful completion of solicitation processes.

Figure 6: The promotion of innovation through to commercialisation in the USA

Although the NIS literature referred to above has emphasised the complementarity between publicly funded basic science and corporate R&D, what is distinctive about the current political strategy is both the greater integration between public and corporate activity dissolving to an extent the division of labour between them; the strategic goal direction; and the urgency of the programme, setting time frames for results. In innovation terms, it can be seen as 'directed evolution' – a combination of strong steering, but retaining the context for variety generation through competing initiatives. Following and adapting Tushman and Anderson (1986), we might describe this early phase of the new industry as a *directed era of ferment*. Europe has no programme of an equivalent scale for the development of biofuels, and there can be little doubt, especially after the UN Copenhagen summit on climate change in December 2009, and the inability of the US president to commit to targets of carbon gas reduction, that the primary political consensus that underlies the US drive to biofuels is based on concerns of energy security and independence.

Taken overall, the US political shaping of the transition to biofuels entails a significant departure from its traditional governance of the economy whether Democrat or Republican: mandated markets, targets for fuel substitution, fiscal incentives on the demand side; massive and strategically oriented state funding of research and research and development, including demonstration plants and commercialisation promotion, on the supply side. This political shaping is a long way from the command economy of wartime, and has some quite different characteristics as a long-term peacetime strategy, but nonetheless reflects a shift in political governance in the face, in the US case, of issues of energy scarcity and security. Although the Obama presidency is suggesting an important move towards strategies also oriented by concerns to mitigate global climate change, the main impulse so far are delivering those outcomes, almost as in early-phase Brazil, as accidental collateral benefits. The irony is that these regions may be delivering these outcomes with greater urgency and rapidity than Europe, where global climate change has been uppermost in shaping the agenda for renewable energy.

5.3 "Europe"

There is considerable and significant variety within Europe in the transition to renewable energy to drive the transport fleets, and there is no intention here to treat Europe as an homogenous entity. Nonetheless, the justification for treating Europe as a region is firstly that European political direction and legislation has been significant in shaping transition, and secondly, there are some distinguishing features common to most of Europe, that stand in stark contrast to Brazil or the USA, both in terms of resource endowments and market characteristics.

Firstly, Europe overall has experienced a quite rapid and remarkable 'dieselisation' of its car fleet, as demonstrated in the switch in dominant fuel use in Europe in Figure 7 below.

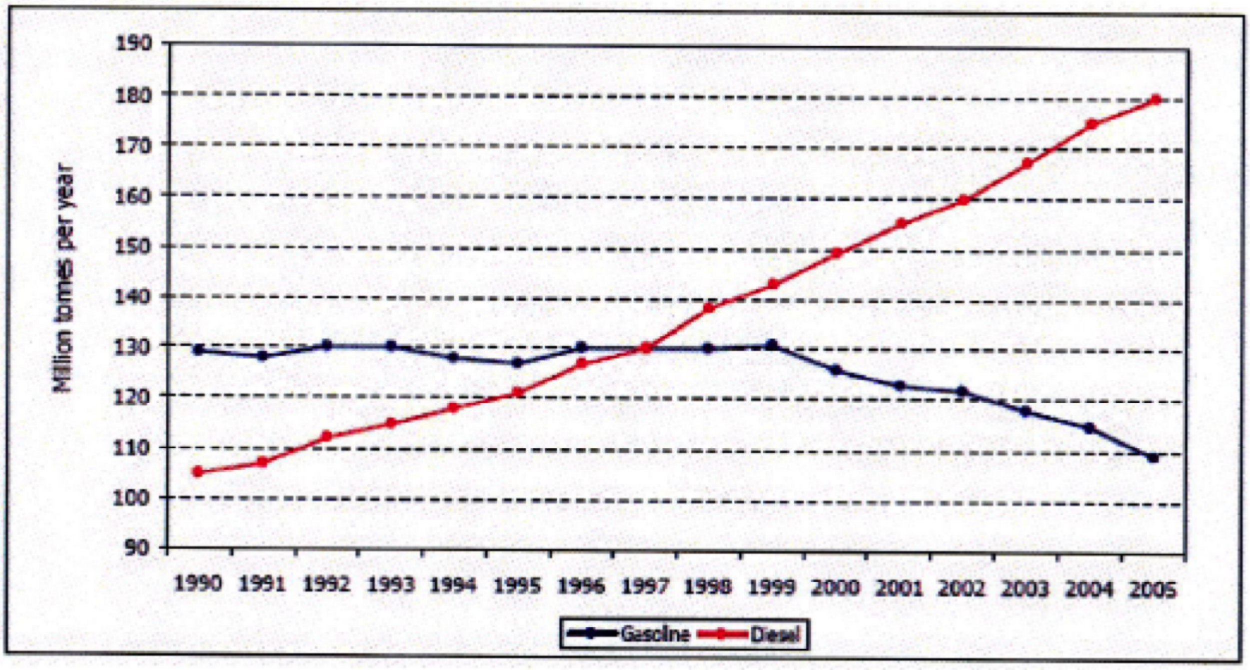


Figure 7: The consumption of petrol and diesel in Europe, 1990-2005. Source: European Biodiesel Association

Currently, over 70% of all new vehicles purchased in Germany, France, Italy and Spain are diesel, creating a significant historical fleet legacy. As a direct consequence of this fossil fuel legacy, biodiesel currently represents 80% of all biofuel usage in the EU. Of this total, 80% derives from rapeseed. The growth in production of biofuels in Europe is radically different from that in Brazil or the USA, both in its timing – scarcely any initial phase dating from the oil shocks – and its content, as illustrated in Figure 8 below.

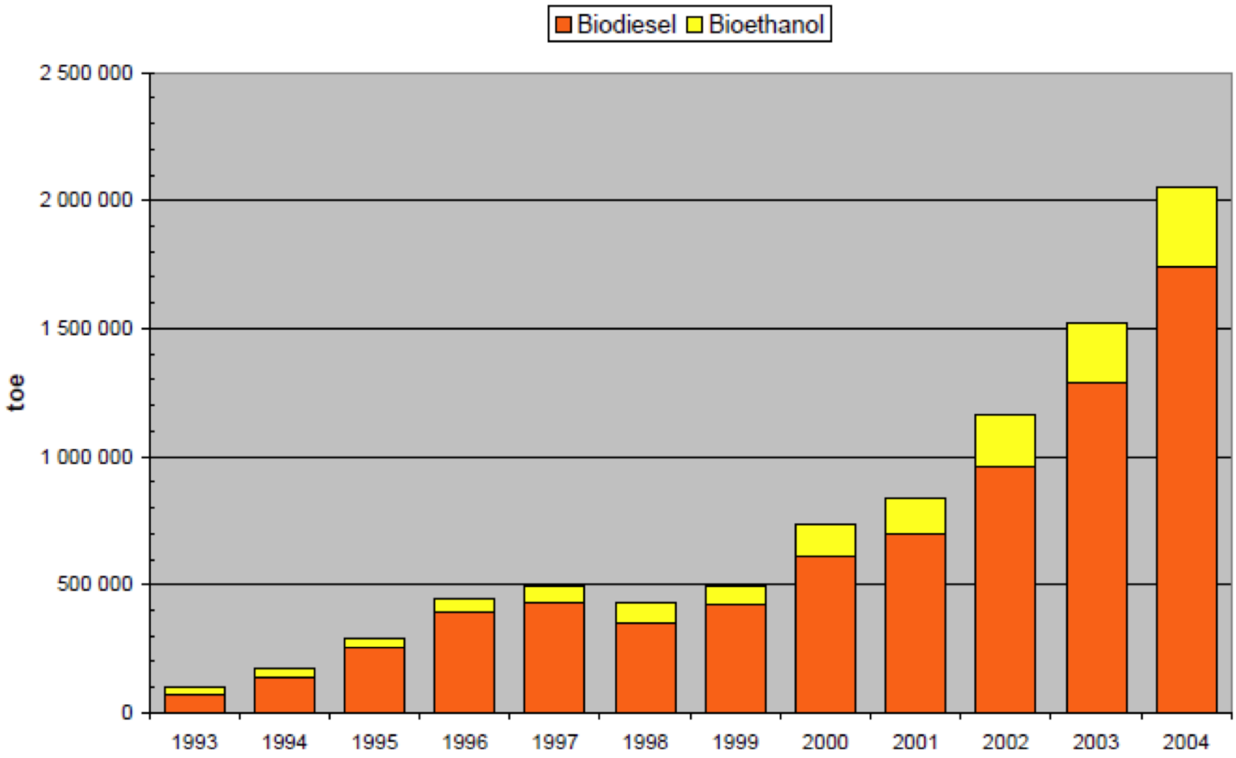


Figure 8: The growth of biofuel production in Europe, 1993-2004. Source: *Biofuels Research Advisory Council, 2006*

As a consequence of dieselisation, the second distinctive European characteristic entails resource endowment, in particular the already established agriculture of rapeseed oil. First used primarily for food and industrial purposes, a massive switch in use and expansion of rapeseed cultivation has constituted the primary biomass for biofuel. Rapeseed is predominantly a temperate zone crop, suited to European agriculture. In contrast to sugarcane, however, its GHG savings are at most one third as significant (Fritsche et al. 2008; CONCAWE, 2007), a level of savings which has a political significance to which we shortly return. But as a consequence, the European Union produces approximately 60% of the world's biodiesel,[21] and only 10% of the quantity of US ethanol. The significance of this resource endowment characteristic is demonstrated by the exceptional case of Sweden, which, as one of the leading European consumers of biofuels, imports Brazilian ethanol, under special exemption legislation from the EU: its biomass potential excludes rapeseed as a significant source, and ethanol from wood alcohol, given the slow growth, low sun, environment, inclines Sweden bioenergy dependent for external resources.

In terms of the political shaping of the transition to biofuels in Europe, political instruments were developed relatively late compared to the other regions, with the first European Directive (European Commission, 2003) appearing in 2003, followed by a further Directives on Renewable Energy and Fuel Quality in 2009 (European Commission, 2009). In policy terms, they established some parameters for stimulating the development and adoption of biofuels, setting overall targets for use of renewable energy for transport. The subsidiarity principle allowed for, and indeed provoked, a wide heterogeneity of national biofuels policies across Europe, ranging from mandatory usage (the Renewable Fuels for Transport Obligation) in the United Kingdom to fiscal incentives to production and use of biofuels at varied rates both within and between countries for different biofuels (biodiesel and ethanol) and at different levels of blends.

In marked contrast to the other regions also, the dominant orientation of the legislation was

[21] OECD (2008) Biofuel Support Policies; An Economic Assessment

developed first in the context of the EU's adherence to the Kyoto Protocol process, and the aim to reduce carbon gas emissions. Fostering European agriculture was a secondary support to the policy, and only recently has energy security emerged as a subsidiary aim (Londo and Deuwaarder, 2007). So the setting of targets was addressing the issue of GHG emission mitigation, rather than finding a long-term alternative to diminishing fossil fuel resources, or political insecurity of supply. The first targets set in 2003 aimed at achieving 5.75% of biofuels for transport fuels by 2010, a relatively modest target, but, without the type of measures adopted in other regions, one that has not been reached by any European country, except Germany. The actual level of UK replacement of petrol/diesel with biofuels stood at 2.6 per cent in 2009 (Renewable Fuel Agency, 2009), far below Germany (7.3 per cent; Government of Germany, 2008), France (3.57 per cent; French Authorities, 2008), and Sweden (4 per cent; Swedish Government, 2008).

However, between the first EU Directive and the second, major controversies emerged over the policy on biofuels, with the papers of Searchinger (2008) and Fargione (2008) having a distinctively European impact – given the orientation of the initial policy. These papers raised new questions on the sustainability of biofuels, especially as a consequence of Indirect Land Use Change resulting from the switching the use of maize in the US from food (animal and human) to fuel (bioethanol). At the same time, food price spikes in 2008 were also widely attributed to the use of food crops for biofuels. Here is not the place to discuss both these two issues, beyond noting that they have since been subject to considerable controversy and criticism (McMeekin et al. 2009; Pilgrim and Harvey, forthcoming). Nonetheless, the environmentalist and food NGOs took full advantage of the controversies to campaign vigorously for a moratorium on biofuel adoption, supported by environmentalist political parties across Europe. In the UK, a report was urgently commissioned which urged caution, and the application of much stricter sustainability criteria to biofuels, and the restriction of use of land for production of biofuels to degraded, non-food agricultural land (Gallagher, 2008).

Although the change in European policy evident in the 2009 directive cannot be attributed solely to these political responses to Searchinger and food price rises, the 2009 Renewable Energy Directive is significant in a shift from promoting biofuels to 'renewable energy' of any kind for road transport in setting its revised targets. This specifically allows for national policies to promote electric cars, provided that they use 'green electricity' to a sufficient extent.[22] The new target of 10% renewable energy for transport by 2020, both in terms of level and direction of support for biofuels, contrasts markedly with either the achievements or ambitions of the policies of Brazil or the USA.

Moreover, and more significantly, it established a regulatory regime for the sustainability of biofuels for the first time. The Directive requires 35% greenhouse gas savings from now until 2017, and 60% GHG savings from new installations and processes thereafter. A review, and possible tightening of sustainability criteria, is timetabled 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.

The GHG emission reduction targets have been set at 35% conveniently to allow the continued production of biodiesel from rapeseed, produced in Europe, until 2017. This corresponds, moreover, to governmental policy in France, where national quotas for biodiesel have been set, and granted to the national rapeseed farmers federation (Sofiproteol and Diester Industrie), giving them a national monopoly of biodiesel production. The policy has been described as 'green protectionism' (Erixon, 2009), particularly in relation to ethanol imports, now under a protective tariffs ranging from 39% to 63%. Nonetheless, the charge of 'green protectionism' from a WTO perspective points to European regulation being ahead of the game, on the one hand, and to major obstacles to achieving internationally agreed sustainability standards on the other. However, the sustainability requirements beyond 2017 will present a considerable obstacle to using rapeseed as the feedstock for biodiesel. Ironically, although receiving much less environmentalist scrutiny than the maize for ethanol effects on

[22] There is considerable controversy over the sustainability benefits of electric cars, given that the current battery technologies result in a suboptimal level of use of green electricity, as a consequence of energy degradation between generation and use.

Indirect Land-Use Change, the switch from oil from rapeseed for food and industrial uses to biodiesel has undoubtedly been a much more direct and immediate stimulus to the increasing imports of palm oil, and the expansion of palm oil production in Indonesia. More ironically still, the application of sustainability regulation to biofuels alone,[23] without the active political direction of finding technological alternatives to liquid fossil fuels of sufficient scale or scope, may result in the accidental collateral damage of achieving less sustainability than the two regions that have not imposed any sustainability regulation. Current failures to meet even modest targets are indicative in this respect. Yet, the singling out of biofuels for special sustainability regulation treatment highlights the difficulties of developing a political framework for regulating sustainability, establishing standards and measurements, across the full range of production and consumption.

"Europe" thus shows great heterogeneity – Sweden importing Brazilian ethanol at one extreme, France fuelling itself on home-grown biodiesel at the other – but provides widespread evidence of new forms of political regulation of economies. The long term strategic targets and the ratcheting-up of sustainability standards are different from measures taken in other regions, but no less radical. Both the heterogeneity and the fact that biofuel sustainability has been so contentious in Europe reveal the consequences of the politicisation of markets, and the fact that experimentation with different political modes of governance leads to outcomes that entail compromise and conflict. The sustainability regime in Europe, up to this point, can be seen as quite unstable compromise between outright opposition to biofuels, and attempts to promote technological routes to renewable and sustainable transport energy. To achieve regional political unity of purpose presents difficulties quite peculiar to the European political environment.

6 PATHWAYS AND POLITICISATION

The modes of political governance of capitalist economies developed since the Second World War appear incapable of addressing the present major challenges to economic stability, let alone growth, arising from global climate change and petro-chemical depletion. From the evidence in three regions, Brazil, the USA and Europe, new modes of politically instituting economies of energy, here discussed in relation to biofuels and transport energy, some quite novel long term strategic shaping of transitions away from fossil fuel dependency are at the early stages of emergence. These are summarised in Table 1 below.

There have been many studies looking at the policy options that could or should be mobilised to stimulate environmental innovations (Soete and Arundel, 1995) and more broadly to precipitate a transition to more sustainable socio-technical systems (Kemp, 1997). These studies provide ample evidence that a policy toolkit exists and is being used by governments to stimulate innovation, but it typically stops short of asking what this means for our understanding of how capitalist political economies might be changing in response to the growing sustainability challenge. This is what we have set out to do on this paper. We have suggested that the early experiments in policy design to deal with CFCs, lead in petrol, SOx emissions and so on could well prove to be the harbingers of a more profound shift in economic governance at national and international scales.

Developing the issue further, challenges of environmentally sustainable economic growth have the potential to elicit a transformation in capitalist political economies and the ways that they are politically instituted to generate new knowledge to solve societal problems. This is going further than considering the policies that might be mobilised to steer innovation systems in a different direction. It is closer to the types of sweeping change described by Freeman and Perez, but in this instance politico-economic transformation is not an adaptation to the emergence of new technological systems, but precondition for their active development.

To look at these potentially sweeping changes, three distinctive pathways, derived not only

[23] No sustainability criteria are imposed on fossil fuels, such as petrol or diesel, even though the increasing reliance on non-conventional resources over coming decades (tar sands, shale oil, deep sea oil) results inevitably in an increasing carbon footprint. Even with conventional oil extraction, there is considerable variability in footprint depending on the extent of flaring. Equally, no equivalent sustainability criteria are in force for other types of agricultural biomass, whether used for food , cosmetics or other industrial purposes.

from pre-existing conditions and natural resource endowments, but from different political cultures and regimes, have been analysed. Abstractly, there are some important common and novel features, as well as some shared instruments. Perhaps the most important entails the development of a political orientation of innovation – directed evolution and development – guiding a long-term strategy of transition. The orientation of that direction differs markedly between the three regions: broadly, development, energy security, and global market opportunity arising from the drive to sustainability in Brazil; overwhelmingly an orientation of energy independence and security in the USA; and greenhouse gas emission reduction and sustainability in Europe. But they are all long-term transition strategies, shaping innovation pathways. We have seen just how different are the consequences of these political orientations and natural resource endowments: advanced and advancing technologies of sugarcane based ethanol and green electricity in Brazil; maize and second generation ligno-cellulosic ethanol in the USA; rapeseed oil based bio-diesel and largely imported bioethanol in Europe. There are also marked differences in what is included in the technological system: in Brazil, notably, we have seen the emergence of a novel fuel-powertrain system; in both the USA and Europe, a more directive policy towards fuel, with some stimulation of a shift to electric cars, but without an overall systemic energy-powertrain innovation drive.

In addition to the orientation of the politically directed innovation pathways, there has been a raft of political instruments, some of which are common across regions. Mandates for fuels, combined with targets for growth in their market share, provide an example of strong, obligatory demand regulation, an innovatory political technology for bringing about transition. More traditional fiscal incentives have been widespread. Brazil and the USA stand out for the scale and strategically pro-active, long-term, state engagement in direction and funding of scientific development, R&D, and the commercialisation of new technologies related to energy transition.

The three pathways differ both in the force with which the State has been directing innovation and the degree to which the intervention has attempted to produce technological variety. For Brazil, the state has been the principal driver, with a tight focus on one technological trajectory developed by a very small number of firms. The result has been the establishment of a highly successful biofuel innovation capability, but one based on relatively little technological variety and competition. In the European case, state intervention has been weaker, but still significant. There is considerable variety, but limited progress in the technology development. The USA example has combined the strong forcing of the Brazil case, but with an effort to maintain a relatively high degree of technological variety. In this case, there are multiple firms, and types of firms, competing within the politically constructed trajectory. These differences illustrate the complex interactions between political and economic modes of instituting economies of energy.

But, as has been manifest more broadly in the Kyoto Protocol and its successor UN initiative at the Copenhagen conference, politicisation of the direction of economic innovation brings political controversy and conflict in its trail. In the USA, energy security and independence can lead to strong measures to reduce dependency on imported fossil fuels, hence, collaterally bring about reductions in GHG emissions. But political consensus on the regulation of sustainability, in the face of powerful oil interests and global climate change sceptics, is currently obstructing the development of a long-term sustainability strategy as a driving force of innovation in the USA. In Europe, conflicts around technological solutions to sustainability have resulted in uneven and highly partial sustainability regulation, and relatively low level of political drive to address the consequences of petro-chemical depletion by promoting active development of alternatives to fossil fuels. The concern to meet carbon reduction targets overshadows concerns to free transportation from reliance on oil, hence the modest targets for renewable transport energy characteristic of Europe. Uniquely in Brazil, achievements of high levels of sustainable transport energy has been supported, over a long period, by a sustained consensus for achieving development based on natural endowments, whether from sugarcane or hydro-electricity, even across a major rupture in political regime from military dictatorship to presidential parliamentary democracy.

This contrasting picture of pathways to politically instituted economies of transport energy in the three regions leaves many issues unresolved. Attaining international standards for sustainability, across the full range of production and consumption, and an international political drive to post-fossil fuel economies, are certainly not facilitated by these divergences of orientation and trajectory. In some ways, biofuels have provided a touchstone for exploring these dynamics: at least in Europe, the introduction of novel bio-based fuels, competing for use of land with production of food, brought to the surface much broader question of sustainable economic growth. As such, these biofuel pathways only reveal the scale and complexity of bringing about the major transformation required. The question is not so much the transition to any one techno-economy of energy, for transport or any other sector, but the transition to new, and international, forms of political governance of capitalist economies. We hope that this preliminary analysis of biofuel pathways has begun to ask that question in a more systematic and integrative manner.

Table 1: Three pathways to politically instituted economies of transport energy.

	USA	***Brazil***	***"Europe"***
Biofuel technology systems	1.Maize to ethanol up to 2002 – oil shocks and Energy Security Act 1980 2. First emergence of commercial ligno-cellulosic ethanol	1. Sugarcane based ethanol – oil shocks 2. 100% ethanol car fleet, followed by FFV. 3. Emergence of biodiesel 4. Co-products and bio-electricity	1. Rapeseed based biodiesel, small scale bioethanol, multi-sourced.
Resource endowments	1971 peak oil, corn belt, extensive land mass	Sun, sugar, new oil, extensive land mass	North sea past peak oil Sugar beet, rapeseed Countries with limited land mass
Dominant drivers	1. Energy Independence and security	1. Energy independence 2. International market opportunity	1. Climate change mitigation
GHG mitigation gains	Maize-ethanol LOW Ligno-cellulosic HIGH	Sugarcane HIGHEST	RME biodiesel MEDIUM
Target-setting for shift to biofuels v alternatives	High targets, 30% by 2030; 20% reduction of oil by 2010. 2005 Energy Policy Act	No ethanol targets, but price regulation, followed by liberalisation. 40% bioethanol achieved by 2008	Renewable Energy Directives 2003 and 2009, moderate targets, subject to downward revision
State shaping of innovation	Large scale investment in R & D Grant and loan guarantee scheme for first-of-kind commercial scale biorefineries. Biomass Research and Development Initiative Genes-to-Life Recent moves to promote electric cars?	Proálcool programme driving bioethanol development State promoted vehicle manufacture (Centro de Tecnologia Aeronautica) deals for 100% and FFV. Petrobras as quasi-state oil company coordinating bio- and fossil fuel FAPESP supported Bioenergy 'BioEn' programme, full spectrum research crop to wheel.	FP7 initiatives on bioenergy and biorefinery, relatively small scale. Tax incentives for energy efficient cars.
State shaping of market demand	Mandates for biofuels Mandate for l-c set at 36 billion gallons by 2022. Tax incentives for fuel blends	Mandates for biodiesel Tax incentives for FFVs, cross subsidisation of fuel price Direct market price regulation then relative deregulation	Mandates Tax incentives for biodiesel, and bioethanol – now withdrawn
State shaping of sustainability regulation	None with respect to biofuels. Emerging in California	Zero deforestation Sustainability certification development Better Sugar Initiative	GHG saving standards, 35% saving as minimum, rising to 50% by 2017.
State shaping of international trade	Tariff barriers	Major exporter to US, Europe (esp Sweden), market-led, state-supported.	Tariff barriers, plus some nationalistic markets (esp France).
Non-governmental political shaping	Insignificant	Insignificant	Major role of NGOs influencing sustainability regulation and target moderation.

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