

To cite this article correctly, please reference as: Gregson N, Watkins H, Calestani M (2013) Political markets: recycling, economization and marketization, *Economy & Society* 42: 1 – 25.

## **Political markets: recycling, economisation and marketisation**

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## **Abstract**

This paper considers recycling as an economic activity, locating it in debates about economisation, marketisation and performativity. It argues that recycling is a reflexive intervention in economic activity which extends the boundaries of markets, by internalising objects formerly externalised as wastes and by attending to the temporal properties of materials. It differentiates between activities based on manufacturing recycled products and the activities of materials recovery linked to commodity markets in secondary materials. By taking the *in vivo* economic experiment resultant from the UK's Ship Recycling Strategy as its empirical focus, the paper demonstrates how recycling connects to wider debates about experimentation and the constitution of markets, and shows the importance of assaying and assay devices as market devices to the economisation of recycling. It further shows that, in materials recovery, measurement is estimation and things are hard to pacify. This makes recycling difficult to stabilise as an economic activity. The consequences are considerable: notably, the possibility of economic failure can threaten to contaminate stabilised (or 'cold') forms of politics. The importance of contracts as a means to securing politicised markets in secondary materials recovery is indicated.

**Key words:** recycling; economisation; performativity; assaying and assay devices; ship breaking; waste

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For most of the social sciences, recycling is synonymous with waste, identified with domestic behaviours and practices (Price, 2001; Barr et al, 2001, 2003; Darby and Oates, 2004; McDonald and Oates, 2004; Tonglet et al, 2004; Hawkins, 2006; Alexander et. al, 2009; Bulkeley and Gregson, 2009), and associated with the governing of municipal waste (Bulkeley et al. 2007). Research rarely makes the connection from the above activities to secondary resource recovery; to see recycling as an economic activity distributed across commodity markets in secondary materials, and as involving the activities of materials recovery and the manufacturing of products made either wholly or in part from these materials. Even within industrial ecology – where the importance of recycling to economies, as a means to closing materials loops, is recognised – the emphasis is more on the principles and policies that promote recasting economies through ecological thinking and documenting material flows (Frosch & Gallopoulos, 1989; Ehrenfeld & Gertler, 1997; Desrochers, 2000, 2002; Terazono & Moriguchi, 2004; Gibbs et al. 2005; Zhu et al. 2007), than on what might be termed, to adapt Çalışkan and Callon's (2009, 2010) phraseology, the economisation of recycling.

That work on recycling can be characterised thus is in no small part because, until very recently, recycling, recycled products and secondary materials recovery did not figure prominently within the economies of the global North. Here, waste was the classic externalised good, externalised by economies, economics and economic knowledge. Discarded and either disposed of through land-fill or incineration, or exported – for the most part to countries in the global South and to China - post-consumer wastes and the residues and wastes of industrial production have long been 'out of sight/out of mind', to their generators as well as to those who analyse and write about economies.

What marks the current moment out, however, is that wastes have become political objects. In the interests of environmental and social justice, it is seen to be important that wastes are dealt with closer to home, that is within the countries that historically have acted as waste exporters, rather

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than being 'dumped' on developing nations (Clapp, 1994; Sánchez, 1994 cf. Montgomery, 1995).

Critical here is the Basel Convention's regulation of the trans-boundary movement of hazardous wastes, and adherence to the proximity principle (O'Neill, 1998).<sup>1</sup> The same principle informs recent EU regulation under the Waste Framework, where directives such as those relating to end-of-life vehicles (2000) and electrical and electronic waste (2003) have sought to prohibit the flow of specific end-of-life goods out of the EU, by classifying these as comprising of hazardous wastes. At the same time, a raft of measures consequent upon the EU Landfill Directive (1999) seeks to divert expended materials from the EU waste stream, through the twin prongs of an increasingly steep tax on landfilling and parallel policies which promote materials recovery and recycling. These measures have resulted in EU member states needing to achieve compliance with a progressively stepped series of recycling targets; they underpin all interventions in EU municipal waste governance; and they are increasingly significant for manufacturing activity, where the costs of landfilling industrial wastes are becoming increasingly visible on the bottom line.

Governing wastes by constricting and diverting flows in end-of-life goods and expended materials has been achieved in the name of ethical responsibilities, duties of care, and social and environmental justice, but these interventions also carry economic implications: they require that recycling be economised. Hitherto, these economic implications have remained largely tacit, but it is these implications, and the challenges of economisation, that lie at the heart of the paper. The crux of what is at stake is as follows. Notwithstanding enhanced regulatory control, much by way of spent goods and recovered materials still finds its way into international markets, particularly to

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<sup>1</sup> The Basel Convention seeks to control trans-boundary movements and the disposal of hazardous wastes in the interests of human health and environmental protection. It was established in 1992, following increased international concern about the heightened levels of toxic dumping in LDCs consequent upon the tightening of environmental regulations in the then industrialized countries (<http://www.basel-int>).

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China and to African countries (EEA, 2009).<sup>2</sup> This is because – as Alfred Marshall long ago recognised – ‘wastes’ are matter out of place; once transported to another place, or to another value regime, they can become resources. Global markets, then, work to move discarded and spent goods, as well as recovered materials, from the global North to countries where established markets in secondary materials recovery link to secondary processing to create new circuits of value. Recent supranational political interventions in governing wastes, however, contest that wastes are resources for developing countries and the emergent economies. Instead, they introduce new, spatially bounded, conditions to markets in end-of-life goods, insisting that discarded and/or spent goods and recovered materials be transformed into tradeable goods, not through externalisation but through internalisation, in this instance within the boundaries of the EU and/or the OECD area. Such spatially bounded re-qualifications necessarily involve the creation (and subsequent expansion) of new markets in secondary materials and their recovery, as well as in recycled goods.

One attempt to constitute a spatially bounded market from end-of-life goods and materials recovery comprises the empirical case for this paper: the UK’s Ship Recycling Strategy. A degree of contextualisation is necessary here in order both to frame this particular political-environmental intervention and to flag the economic difficulties facing projects, like this one, that seek to economise recycling within the boundaries of the EU, often in the face of long or well established global markets. The global market in end-of-life merchant ships is typically of the order of 600 – 1000 vessels per annum, and currently over 80% of annual commercially scrapped tonnage moves

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<sup>2</sup> The Bureau of International Recycling notes that, before the current recession, the global trade in recovered paper and board amounted to over 160 million tonnes per annum. Much of this was destined for China, which imports from North America, Europe and Japan (<http://www.bir.org>). A report by the European Environment Agency (EEA) estimates that in 2005 80% of wastes shipped out of the EU went for recovery (EEA, 2009). The same report states that the EU exported 3.5 million television sets in 2005, and estimates that 1000 units per day, classified as ‘for re-use’, arrive in Ghana, Nigeria and Egypt, but that they are destined for secondary materials recovery.

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to the breaking beaches of South Asia, specifically to Alang (India), Chittagong (Bangladesh) and Gadani (Pakistan).<sup>3</sup> The reasons can be readily explained by standard economic concepts. Cheap labour costs combined with minimal or non-existent environmental regulation mean that the costs of scrapping ships in South Asia are far lower than they are within the EU, where both labour costs and the high costs of environmental compliance mean that firms located there are uncompetitive when bidding for vessels compared to firms based in South Asia. Further, demand for scrap steel is high in South Asia, and even higher in China, which is the major global importer of scrap. Shipping companies, looking to maximise returns on their assets, sell from their fleets those vessels that create insufficient profit margin. Usually these are older ships, typically 25 – 32 years old.

Depending on the relativities of freight rates and scrap prices, the highest bid for surplus vessels will be made from either the second-hand or 'demo' markets respectively. In the demo market ships are valued not for their dead weight tonnes, or carrying capacity, which relates to freight rates, but for their light weight tonnes, that is, as tonnes of metal which might be recovered. So, as the price of scrap rises in South Asia, fuelled in turn by the construction booms associated with rapid urbanisation, demand for ships from South Asian ship recycling businesses increases.

However, the very factors that make South Asian ship breaking economically successful have led to it becoming a matter of concern (Gregson, 2011).

Highly labour intensive and with minimal standards of labour and environmental protection, the South Asian ship breaking industry has attracted considerable controversy, particularly as a result of the activities of NGOs, for whom it came to stand for the dark side of globalisation (Crang, 2010).

Complex chains of exchange work to buffer transactions and ensure that commercially owned end-

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<sup>3</sup> The global market in ship breaking works counter cyclically. Thus, in 2009, during the height of the global recession, > 1000 commercial vessels were demolished (EA Gibson Shipbroker Sales & Purchase reports), whereas at the peak of the boom in global trade in 2007 estimates put that figure at around 600.

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of-life ships like oil tankers, bulk cargo vessels and container ships remain difficult goods for NGOs to pin to particular shipping companies. In contrast, like luxury cruise liners, state-owned (in practice naval) vessels are more readily identifiable, even when they have been sold on by governments. So it was that, in the 1990s and 2000s, the US, French and UK governments all fell foul of NGO and journalistic exposés featuring formerly state-owned ex-naval vessels either being broken up on the beaches of Alang and Gadani or in the throes of being exported there. In all three cases media exposure was followed by political furore, political intervention and then by the development of spatially bounded policies to govern end-of-life naval vessels. Yet in all three cases, the economics of how to effect ship disposal was an afterthought; left to be worked out after the policy and largely through experimentation. This paper uses the case of the UK government's *in vivo* experiment both to show how ship recycling has been economised in spatially bounded conditions and to highlight the economic challenges facing politically induced market qualifications such as this, in which recycling is promoted as a good but without much forethought as to how ethical and environmental values might be turned to economic value.

In this respect, it is important to note that recycling is only achieved physically and economically when recovered secondary materials are exchanged and enter the manufacturing process, thus incorporating them into a further round of commodity production. On this definition, recycling comprises a set of activities which necessitate the destruction of things (here ships) to extract and recover materials (in this instance, mostly metals). Destructive activities therefore have to occur in ways that are mindful of where (and what of) value is to be extracted, and of how destruction might work to maximise extractable value. At the same time, destructive activities also generate residues and wastes, either as a direct result of materials present in spent goods or as an effect of processing techniques. Depending on the goods, these residues and wastes can be benign and/or

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extremely hazardous. So, recycling activities need to be mindful of handling and managing wastes as much as extracting value. In certain instances – paper based and glass products for example – the processes of destruction and value extraction are relatively straightforward. The more complex the product, however, the more diverse its constituent materials and the more complicated the process of destruction-to-extract value becomes. So, complex destructive activities, such as ship breaking, are typically accompanied by an array of sorting and segregation work relating to both extractable value and waste management and remediation. The former prepares recovered, graded materials for sale into the commodity markets whereas the latter generates wastes and ‘disposal’ costs. The crux of all recycling activity, however, regardless of the objects or materials of specialisation, is that the industry has no control over the quality of goods entering the supply chain. Rather, this is a supply chain of goods already made – a legacy of past manufacturing processes rather than of manufacturing to produce a quality controlled product for sale. How then is the potential value in and to be extracted from spent and/or discarded things estimated?

Some sectors of materials recovery – notably textiles – continue to rely on tacit practical knowledge and human perceptual capacities to categorise and grade discarded things (Tranberg Hansen, 2000; Norris, 2005, 2010; Rivoli, 2005). In other sectors, however, and particularly those characterised by complex goods, assay work, including surveying, instrument-based testing, laboratory testing of material samples, and quantifying estimations, is increasingly used to analyse, characterise and classify, and to estimate potential worth.<sup>4</sup> Ship breaking – at least as conducted in the markets discussed in this paper – is one such instance. The technique deployed here is principally surveying, which is used to map, characterise and quantify end-of-life ships as materials. Surveys work to

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<sup>4</sup> We use the term assay here in place of metrology and metrological devices. Whilst Callon and his co-workers use the term metrology as a catch-all for anything involving measurement, many of the activities of secondary resource recovery rely on surveying, estimation and calculation, supplemented by laboratory testing and, occasionally, instrument-based testing in the field. Whilst this includes a form of measurement, this is a long way from metrology’s basis in the science of measurement.

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translate ships from dead weight tonnes to light weight tonnes. In more general terms, then, assaying weaves materiality and value, constituting estimated measurements of secondary materials, and also wastes, from spent, used-up, depleted and/or discarded goods.

The paper shows how the products of assaying are assembled as assay devices, and how the latter relate to the economisation of recycling. Using the vehicle of the economic experiment associated with the UK's Ship Recycling Strategy, we demonstrate that assay devices are central to that *in vivo* experiment. We evidence this latter point by re-citing as a representational experiment the economic experiment performed *in vivo*, which involved tantamount to two identical vessels broken synchronically by two companies in different places. A key point to emerge is that value is not simply realised at the point when recovered materials are exchanged for money in the commodity markets in secondary materials. Rather, value is also performed into being, through assay devices, their categories, and the relation between these categories and the activities of destruction, sorting and separation.

In that assay devices are demonstrated here to be both market devices and a critical part of an *in vivo* experiment in constituting a spatially bounded market in ship recycling, their significance goes beyond the specifics of the empirical case to connect with more fundamental debate about economies as performative (Callon, 1998, 2007; Callon *et al.* 2007; Mackenzie, 2003, 2004, 2006, 2009; Mackenzie *et al.* 2007). Much of the interest here has been in economics' multifarious effects on economies, and particularly how effects are woven into material practices that perform economies into being. Besides Donald Mackenzie's ground-breaking work on equations, which examines how economic knowledge (in the form of models and hypotheses) shapes financial markets and traders' practices, a small but expanding literature has addressed technologies as market devices and their materialisation of economic activities. Examples include telephones, ticker

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tape, and traders' computer screens (Buenza and Stark, 2004; Preda, 2006; Hardie and Mackenzie, 2007; Muniesa, 2008), to which we wish to add assay devices. Muniesa and Callon (2007), however, go further, to argue that the performative character of economies is at its clearest in experiments that use 'real economies' as their test ground. They maintain that economic experiments are a constitutive element in the construction of markets; that experimentation is open to dispute, and that, in this way, economic entities have the potential to become political objects. In so doing, a debate cast largely in terms of economic performativity is opened-up to the political.

The case discussed here confirms the veracity of Muniesa and Callon's arguments about the importance of experimentation to the constitution of markets. But, significantly, it is not a case of economic entities becoming political. Rather, the relation of the economic and the political here is the other way up: here a political intervention is becoming economic, in large part through the work of assay devices. In this instance, the political intervention rests on its capacity to be economised. It is in this last regard that assay devices' basis in calculative technologies of estimation, and their connection to measurement, becomes important. Andrew Barry (2002) has argued that measurement is open to contestation and inventive and performative in its effects. He states:

"Far from creating a clean and secure connection between the world of politics and the world of the economy, measurement becomes a conduit for contamination. The organisation of economic activity becomes a political matter" (2002, p 280).

Conduits are open-ended; their effects are not just one way. As such, the markets constituted through an economic experiment of which assay devices are a key part might usefully be regarded as open to political reverberation, whilst the potential vulnerability of politicised interventions in the market to contamination via the fragilities of estimation are clearly signalled.

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The paper is structured in three main sections. First, we position recycling activities generally within the economisation project of Michel Callon and his co-workers. The argument here is not simply an application of Callon, for whom objects are admitted to economies but as passive goods, whose passivity enables, and is critical to, economisation. Rather, the paper demonstrates that complex end-of-life objects and their constituent materials are active participants in economisation. Second, we proceed to outline briefly the UK government's Ship Recycling Strategy and the conditions of its emergence. Third, we focus on the *in vivo* economic experiment, emphasising the work of assaying and the role of assay devices in the creation and stimulation of this new market.

### **Economisation, marketisation and recycling**

Callon *et al.* (2002) argue that economies rest on qualifying products and positioning goods.

Positioning goods is a continuous process of qualification and re-qualification, through design, production, development, manufacture and retail. As Callon argued in *The Laws of the Markets*, qualification involves law, technology, architecture, accountancy and also measurement, not just economics (Callon, 1998). The aim of qualification is to establish a constellation of characteristics, which stabilise products, and transform them into tradeable goods (Callon *et al. ibid*). Significantly, whilst acknowledging Appadurai's (1986) recognition of the career of goods, for Callon, qualification and re-qualification are processes that end with the exchange transaction that marks the initial act of purchase – the car show room is the example in the key exchange with Miller (2002). Nonetheless, as Callon *et al.* (2002) argue:

“Markets evolve and [...] become differentiated and diversified. But this evolution is grounded in no pre-established logic [...] Economic markets are caught in a reflexive activity: the actors concerned explicitly question their organisation and, based on an

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analysis of their functioning, try to conceive and establish new rules for the game” (p 194).

Recycling, as this is promoted within sustainability discourses, rests on an explicit questioning of primary resources as the basis for the production of manufactured goods. To promote recycling, therefore, is a reflexive intervention in the organisation of markets; one which extends the boundaries of markets by paying attention to the career of goods (Appadurai, 1986) and the temporal properties of materials.<sup>5</sup> More broadly, recycling challenges the externalisation of waste, be that via economic modelling or through physical processes such as discharge, dilution, dispersal and dumping. It is a means to internalize that which was classically externalized. To achieve this, however, rests on the re-qualification of end-of-life, or spent things, and their constituent materials. Or, rubbish needs to be turned to value. The question posed by the internalisation of what was formerly externalised, then, is one of economisation, namely how to make markets of and from spent things, or how to turn unwanted stuff into products and tradeable goods. Supranational interventions, such as those rolled out recently within the EU, and that seek to constrict and divert global flows of wastes, pose precisely those questions but with spatially bounded conditions attached.

Within the boundaries of the EU, then, what are the broad contours of recycling’s economisation and marketisation? Thus far, there are two identifiable components to this. In its clearest form, and just as Callon argues, the characteristic of ‘recycled’ (as adjective) is a defining characteristic of a particular product; it is what makes it a tradeable good. Here stabilising ‘recycled’ is critical to the

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<sup>5</sup> Technically there are limits on the number of times that certain materials can pass through recovery and recycling treatments without detracting from their capacities and properties (e.g. textiles but not metals). Representations of recycling, however, promote a vision of closed material loops and endless circulation.

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product's manufacture, merchandising, retail and consumption. Recycled paper is currently possibly the most familiar example of such a product. Here, the attribute of being made from secondary resources provides the locus for the ethical consumption of a product. It establishes a normative and moral basis for consumer choice, linking the purchase of particular products (writing paper, kitchen rolls, toilet rolls, tissues) with the conduct of an ethical self, whilst positioning the product in a wider network of products whose materiality is expressive of a duty of wider (planetary) care/conservation. The manner of retailing of these products, typically adjacent to the same product but made from virgin resources, also offers a tacit critique of products made from primary resources.

Unlike recycled products, however, for markets in secondary materials to expand and deepen, requires the widespread substitution of secondary materials for virgin materials in a range of manufacturing processes. Here the term 'recycled' is not normally attached to what is being sold. Rather, it is black-boxed within the product. Glass, tin, aluminium, metals, board, plastics – all are like this. Here it matters little to the consumer that what they buy is made in part, or wholly, from recycled materials. But there is plenty of evidence to show that, for manufacturers, the substitution of secondary for primary materials is not a straightforward process. Secondary materials carry risks, some more than others – of contamination, or poor quality control. If incorporated into the supply chain, poor quality materials will threaten the tradeability of the primary good and the reputation of that manufacturer. This signals a broader point: that secondary resource recovery, whilst technically possible, is always a socio-technical project.

Paying attention to secondary materials is not just important to the economisation of recycling. It also allows us to qualify the importance that Çalişkan and Callon (2010) place on the passivity of goods within marketisation. In that paper, Çalişkan and Callon pose the question, 'Is it possible to

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conceive of [...] goods [...] authorized [...] to contribute multiple suggestions of their own value [...]?’ (*ibid.* p. 5). They answer with ‘a resounding no’, arguing that ‘*it is the passivity of things that transforms them into goods* [our emphasis], and that enables agencies to form expectations, make plans, stabilise their preferences and undertake calculations’ (p 5). This may be so with many things, but as we show in the paper, when economic activities are concerned with the destruction of complex things and allied materials recovery, pacification is difficult to accomplish. This is not only because things and materials become animated in these activities, making multiple suggestions as to what they might be, or become, as a tradeable good (Gregson et. al. 2010), but also because socio-technical devices – in this instance, assay devices - struggle to stabilise a process that is open in its possibilities. In the economisation of secondary materials recovery from spent things, the calculative task is the challenging one of how to transform estimated and animate multiples (end-of-life things) into stabilised goods (plural), that is, materials that can be traded in markets. As we show, this type of calculative challenge sits at the heart of the UK’s Ship Recycling Strategy. Before elaborating on this, however, it is necessary to outline briefly the Strategy.

### **Policy and the market: the UK’s Ship Recycling Strategy**

The UK’s Ship Recycling Strategy 2007 evolved from the conjuncture of three developments (<http://www.defra.gov.uk>). The first was ship breaking’s emergence as a focal point in global debate in the late 1990s and 2000s. This, in turn, was a response to repeated NGO and journalist exposés of the working conditions associated with the industry in South Asia, including workers’ deaths, injuries and child labour, and the resultant environmental pollution and degradation (Rahman and Ullah, 1999; Bailey, 2000; Greenpeace/FIDH/YPSA, 2005; FIDH/YPSA/NGO Platform, 2008). Graphic images, documentary films and investigative journalism appearing in western media earned the South Asian ship breaking industry epithets such as ‘Hell on Earth’. General opprobrium

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became specific, as images of identifiable former cruise ships and the tracking of ex-naval vessels pinned ‘dumping’ on western capital and particular states, including the US, the UK and France. As ship breaking came to define the dark side of globalisation for NGOs it became ‘hot’ politics.

Consequently, western governments could no longer ignore or turn the blind eye to what happened to the ‘toxic (naval) ships’ they decommissioned and sold for scrapping.

Subsequently, regulatory concern both at the national and supranational level has been to ensure that ship breaking occurs in ways that meet acceptable environmental and health and safety standards (Basel Convention, 2002; ILO, 2004). Unacceptable standards are identified with activities that occur on open beaches in highly labour intensive conditions, and they remain defined by the industry as this occurs in India, Bangladesh and Pakistan. International regulatory debate through this period has been both protracted and often heated, particularly as it moved toward the 2009 Hong Kong Convention on Safe and Environmentally Sound Recycling of Ships. To chart this debate is not our concern. But the nub is that end-of-life ships are multiple: within the terms of the Basel Convention they are open to classification as *both* ships and hazardous waste, meaning that – when defined as ships - they can legitimately sail to destinations outside the OECD area. For EU member states, however, the designation of end-of-life ships within the terms of the Waste Framework Directive, waste shipment regulations and the Basel Convention means end-of-life vessels owned by, or registered with, member states are classified as hazardous wastes and cannot be exported beyond the OECD area.<sup>6</sup>

The second chain of events influencing the development of a UK-specific policy was the import of four decommissioned US naval ships to a then unlicensed facility in the UK, in late 2003 (Hillier, 2009). The consequent furore made ship breaking a ‘hot’ political issue again in the UK, but this

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<sup>6</sup> It is important to note here that such restrictions can be easily side-stepped, through the widespread practice of re-flagging vessels with ‘flag states’ that are outside the EU.

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time as an activity potentially occurring in the UK. It led, thirdly, to a sequence of reviews and Parliamentary Select Committee enquiries in 2004 and 2005, the upshot of which committed the UK government to the development of a Ship Recycling Strategy.

The strategy aims first to develop a strategic approach to the recycling of UK-flagged vessels, consistent with the UK's wider commitments to international sustainable development. It 'establishes domestic policy for the recycling of government owned vessels, sets out relevant waste controls and recommendations for owners and operators of UK vessels, and informs the UK's position for international negotiations on ship recycling' (<http://www.defra.gov.uk>). Secondly, it promotes the environmentally sound management of ship recycling by ensuring due compliance in relation to all UK-flagged vessels and the conditions in which they are broken up, specifying that recycling be undertaken in conditions of containment, and itemising the permits and licenses required of recyclers and of specific recycling sites. Thirdly, it aims to provide practical support in the form of guidance (effectively a process road map) for both ship owners and recyclers on the regulatory regimes that govern UK ship recycling.

Such are the bare bones of the strategy. In terms of effects, this is a regulatory device that has intervened in the governing of economic life, to borrow Peter Miller and Nikolas Rose's (1990) phrase. Nonetheless, the intervention begs an important question, which is, having blocked the flow of end-of-life UK naval vessels to non-OECD markets, how has the market been reshaped? Or, how have the environmental values, which inform the policy, been translated into economic value? Aside from insisting on adherence to BPV (Best Possible Value) when selling government assets,<sup>7</sup> the strategy states: 'it is not within the remit of this strategy to make recommendations on commercial decisions concerning the establishment of domestic ship recycling facilities'

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<sup>7</sup> The case is another instance of the introduction of market principles into the UK public sector. For further discussions of BPV, and Value for Money (VFM) see Miller (2003) and Alexander (2005).

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(<http://www.defra.gov.uk>). But, creating a market is key to the success of the strategy.<sup>8</sup> In the following section, therefore, we examine the economic experiment that has been set in train, focusing on the work of assaying and the role of assay devices as market devices in the economisation of ship recycling.

### **The UK's Ship Recycling Strategy as *in vivo* experiment**

#### ***Creating and stimulating the market: assay devices and the practices of assaying***

The economisation of the UK's Ship Recycling Strategy has been achieved through creating and stimulating business interest and by working with assay devices to frame ship recycling as an economic activity.

Success in creating and stimulating business interest is discernible in the enrolment of new entrants in the market, the rekindling of largely moribund infrastructural facilities, and in enabling established ship recycling businesses to expand their markets. Of critical importance has been to work out the right kind of business to interest. Knowing which businesses to stimulate is a matter not just of knowing different businesses, their business models and their margins, but of simultaneously learning about, and experimenting in, ship recycling as an economic activity, within the parameters set by the policy. The ground rules are described thus:

“[...] there's no money in it. Even now, when we extract all the metals, what are we looking at? x [figure removed], y [figure removed] million pounds per hull? That is the total value of all the extracted material. Well that's not big business [...] not when you

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<sup>8</sup> In 2009 just three UK formerly government-owned vessels were in the throes of demolition, with another three being prepared for tender (c.f. note 3). In global terms, then, the intervention is numerically insignificant. Nonetheless, however small, without a market, decommissioned UK naval ships would accumulate, putting considerable pressure on space in naval dockyards.

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consider that you have to spend probably 80% of that on extracting the metals and getting rid of the waste. [...] For all those reasons in Western Europe the margins are very poor” (Interview data, May 2009).<sup>9</sup>

Correspondingly, it has been important to go beyond businesses located in Western Europe, to exploit the full competitive advantage afforded by the policy’s application to the OECD area.

Creating a market, however, is not just about stimulating business interest. Key to the market is commercial viability:

“We want to stimulate the market to establish the maximum value of recoverable materials from a ship, and whoever can do that in the most efficient way will have a nap hand and a commercial edge, not just against his own peers in Western Europe but that will be a little bit more competitive against the Asian market, because ultimately – if there’s a long term future for ship recycling within the EU – and the Basel Convention, the IMO – everything about that says that there should be – then that business has got to be profitable, otherwise it won’t happen. If it’s not profitable we don’t get all the safeguards we are looking for” (Interview data, September 2009).

Without commercial viability, ships will not disappear at the rate necessary, whilst the activity of ship recycling would fail to stabilise. Rather, firms would enter, and then quickly leave, the market and the activity would be at best an embryonic, transient affair. So, how is commercial viability being constituted in this market? Importantly, at the same time as the

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<sup>9</sup> The sub-section draws on three separate and extensive interviews with representatives of the Disposal Service Authority, the body charged with selling the UK’s former military assets, in May, July and September 2009, as well as quantitative data supplied in relation to individual ship breaking projects.

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above comment cites the efficient market hypothesis, it highlights the importance of extracting value to recycling. In this regard, the work of assaying is critically important.

Assaying in ship recycling is founded on surveying and surveys. Surveys are performed either by, or on behalf of, disposal agencies and recycling companies. Any vessel disposed of by UK government is accompanied by a Green Passport, which comprises an inventory of the known hazardous materials aboard a vessel. An example is provided in Table 1.

Table 1 about here

The passport acts as a record of a ship in hazardous materials, as the basis for constituting plans for its destruction and recycling, and as a regulatory document permitting the disposal of that vessel. Nonetheless, although assembled from independent surveys (of asbestos, paints, plastics, PCBs, gases, chemicals and oils, as well as general wastes), currently Green Passports provide no more than retrospective summary metrics of materials present.<sup>10</sup> Further, in legal terms they are qualified as estimates rather than accurate records. The task of assaying for ship recyclers, therefore, is to use their own independently commissioned surveys both to check the accuracy of the passport and to translate that passport into the logistics (and costs) of hazardous waste remediation, set against the potential value that might be extracted from the vessel in metals.

Experienced ship recyclers divide assay work into two phases: pre tender and extracting value as part of the recycling process. Pre tender work focuses on surveying anticipated hazardous materials. A case in point is Company A based in continental Europe, inspecting a high risk

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<sup>10</sup> The intent is that the Green Passports required of future new build vessels under the Hong Kong Convention will enable the recording of materials present at manufacture and of any subsequent materials added through sequential repairs and refits over the standard 25 – 32 year life of a vessel in the merchant fleet.

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and politically controversial vessel released for tender. Reckoning the asbestos estimates supplied by the disposal agents to be inadequate, and the methods of surveying deployed problematic, this company took five asbestos specialists with them on the inspection visit, both to provide independent surveys and to translate survey plans to a reliably costed programme of asbestos remediation work.<sup>11</sup> Assaying here, then, is about converting environmental values, expressed as metrics of asbestos present, to economic costs, expressed in the labour time of asbestos remediation and disposal costs. Similarly, Company B based in the US, takes a full compliment survey team on pre tender inspections, comprising specialists for hulls, paints, asbestos, oils and towing, with laboratory testing of samples for all hazardous materials being standard. In their case, the perceived need for this assay work is a result of learning the hard way: failing to sample the paint work on a successful bid, they found themselves landed with a vessel covered in PCB paint and “a mega paint removal job”.

In contrast, less experienced companies and new market entrants tend to work off the inventories supplied with vessels and/or fewer independent surveys. As well as often underestimating the uncertainties of hazardous wastes, these businesses typically have less experience in translating estimates of hazardous wastes into logistics and costs. So, what might look a low risk vessel in terms of the amount of asbestos estimated to be present might actually be high risk, because the stuff turns out to be everywhere aboard rather than localised. Or, what might seem a relatively innocuous problem on paper – say the presence of x litres of oil – turns out to be a logistical nightmare because the vessel to be disposed of is a

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<sup>11</sup> Even for experienced asbestos surveyors there are considerable uncertainties in estimating asbestos aboard end-of-life naval vessels. This is because ships are relatively unfamiliar and bespoke structures, particularly when compared with buildings. Further, large areas of a vessel remain inaccessible to surveying. So, whilst an informed best guess will suggest where asbestos might be expected to be, or should be, present, its physical presence (or not) will only manifest itself in the course of the work of removal and demolition (see Gregson et al. 2010).

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fleet oiler.<sup>12</sup> For those inexperienced in the business and in the practices of assaying

hazardous wastes, the potential to incur considerable additional financial costs will be readily apparent.

On the other side of the recyclers' balance sheet, assaying is about maximising extracted value. A vessel's light weight tonnage, itemised on its Green Passport, provides a reasonable estimate of the baseline yield here, which is the amount of ferrous scrap that will be generated in its destruction. But there are no guarantees as to how estimates might translate to profit. Market volatilities in ferrous scrap spot prices are considerable, ranging from an unprecedented high of \$700/tonne to the mid \$200s during this research. Consequently, whilst selling high can make one ship recycling project more profitable than another, where the real money is to be made in ship recycling is in the amount of non ferrous extracted.<sup>13</sup>

Uncertainties about the amount and type of non ferrous present are also considerable, but assaying work during the destruction process acts to maximise the non ferrous and stainless steel extracted. Experienced ship recyclers therefore have separate zones dedicated to the careful sorting of non ferrous – aluminium and copper, nickel and gunmetal – and of stainless steel. In ship recycling, even in Europe and the US, this form of assaying work is still done manually, by what one ship recycler describes as the “well trained eye” of a metal worker, who is able to instantly identify not just different metals but distinguish concentrations, such as the difference between a 90:10 copper-nickel alloy and a 70:30. Manual, perceptual assay

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<sup>12</sup> Without going into the technical intricacies, fleet oilers might usefully be regarded as the equivalent of sea-going petrol stations or fuel depots. Not only do they comprise multiple fuel storage tanks but they also have labyrinthine pipe work and refuelling systems, all of which will contain much by way of heavy oil residues. Hazardous wastes therefore both permeate and contaminate much of these structures and will be unavoidably released in their destruction. The waste management and remediation on such a vessel would be both technically challenging and very costly. A similar situation occurs when asbestos is distributed throughout a vessel.

<sup>13</sup> An indication of the relativities during the period when the research was being conducted is as follows: ferrous - \$270; stainless steel - \$1000; aluminium - \$1440; copper - \$3138 (January 2009 data: London Metal Exchange prices in US dollars/MT).

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work is about reading colours and colour tones: “the reddish tones that make it a G-metal and the different red that makes it an M-metal” (US-based ship recycler, field data 2009).

Alternatively, portable hand-held alloy analysers can be used to provide a point-based chemical compositional analysis, but these are costly devices and slower at characterising piles of metal than the well trained eye.

Such is the work of assaying, as practiced by ship recyclers. But assaying is also deployed by disposal agents, this time to constitute what might be termed an assay device, as a calculative market device.

Table 2 provides an example of how assay devices are assembled by disposal agents from the work of surveying and estimation, to work as calculation.

Table 2 about here

Three points matter here. The first is the categories recognised. These are not ontologically exhaustive but rather establish how ontology relates to extracted value and the costs of waste disposal. Metals are differentiated, with the non-ferrous being further subdivided, but note not exhaustively so. Another category relates to the main hazardous waste known to be present in these vessels, asbestos. Secondly, projections are always estimates. Here the role of assay devices is to stimulate the market and not just, as with recyclers’ assaying, to provide accurate estimates. So, in assembling this projection of a ship as metals and as wastes, this disposal authority has, on the one hand, used their asbestos survey to place a wide estimate on that category, allowing recyclers what appears to be due recognition of the costs of asbestos handling and disposal in Western Europe. On the other, it has placed a more conservative estimate on the relativities of the quantities of ferrous and non-ferrous metals.

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To stimulate the market, therefore, assay devices are used to suggest to ship recyclers that there will be enough non-ferrous material recoverable to make it worth tendering a cash positive bid for that vessel.

A third point relates to how assay devices perform as calculation, that is, as estimates of materials recovered and value extracted. Table 2 therefore is not just of a ship as projected and as extracted materials, but a means to begin to benchmark the relative performance of projects (and firms), and of assessing the confidence that can be placed in assay devices as market devices. We see here, however, that even with wide margins on asbestos, the return exceeds the estimate. Not only will this have commercial, and potentially environmental, implications but it also has potential consequences for preparing future vessels for tendering:

“[...] 43 tonnes, is that so far [out – Table 1] that we really need to look at the survey? [...] Are we asking the surveyor to look in the right compartments or indeed, I don't suppose we are. We are not telling the surveyors anything. We are saying, 'Look, there's a ship, go and tell us where the asbestos is'. [...] A lot of the additional asbestos that was not picked up in the survey came as a result of a false ceiling. We don't want to do a Type 3 asbestos survey [invasive] because you start to expose [asbestos] but actually the idea of [...] taking away false ceilings might be an investment worth making”  
(interview data, May 2009).

At the same time, the relativities of ferrous versus non-ferrous within Table 2 suggests where this ship has been turned to value by the recycling company, not as scrap steel but through the recovery of non-ferrous metals, notably in this instance copper and aluminium. But, as significantly, assay devices offer no certainties that there is an accord between categories and recovered materials. Recognising that the order of magnitude price difference between

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stainless steel and ferrous is a time-honoured means of “keeping Scrappies in Bentleys”, disposal agents resort to audits comprising a series of checks on the ground and an insistence on the regular reporting and sharing of commercial data to ensure due compliance and to provide confidence in the practices of particular firms. A reliance on inspections to supplement regular project reporting, however, shows that assay devices offer no control at a distance, and that they are imprecise centres of calculative agency.

### ***Experimenting in extracting value***

If assay devices are central to the stimulation of the market, they also connect to the wider *in vivo* economic experiment. The over-arching hypothesis is that end-of-life ex-naval vessels have value, but value is known to be geographically contingent, in that ship x is known *a priori* to realise less value when broken up within the boundaries of the OECD than it would if broken up beyond those boundaries, but how much less? The working hypothesis in this economic experiment is that sufficient value can be extracted from end-of-life ships within the OECD to make the activity commercially viable. Assay devices work to operationalise the working hypothesis but they are critical to a stronger form of that hypothesis, which is that the value of ships being broken up within the OECD area will increase through inductive experimentation, as knowledge improves and as assay devices are applied and refined. In this section we perform a representational experiment that in turn re-cites the initial experiment performed by those experimenting in constituting the market. This highlights the diverse ways in which value is extracted from end-of-life ships by firms; firms’ experimentation in and learning from this new market; and the connection between these

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activities and the wider *in vivo* experiment.<sup>14</sup> It also shows that end-of-life ships are far from passive objects in their economisation, but rather, multiple and open in their possibilities.

Individual firms have different modes of breaking ships and recover materials in different ways. This relates to value extraction and profitability. Table 2 includes the materials out-turn of one project conducted by an experienced ship recycling business. In this facility vessels are broken up sequentially, deck-by-deck. Whilst the vessel is still afloat and moored at a pier, decks are first stripped of hazardous waste materials. Then, 'hot (i.e. manual) cutting' using oxyacetylene torches, combined with heavy lifting cranes, is used to recover metal from the disintegrating ship. Once the vessel has been reduced to the waterline, what remains is pulled onto a slipway, where hot cutting is accompanied by 'cold cutting', or the use of a hydraulically-operated shear, to tear and reduce ferrous metal to industrial process-facing sizes. These operations connect to further manual sorting and segregation of non ferrous metals, prior to being sold into commodity markets.

The principal advantage of the above method is that it is ideally suited to the maximum recovery of non-ferrous, as well as ferrous, metals. Equally evident in Table 2 is the problem this project had with asbestos – which led to a significant project over-run and considerable additional costs. Two points followed from this. First, having destabilised commercially, it was necessary for the project to be re-stabilised. Since assay devices had failed as a calculative device, other market devices had to be retrospectively deployed. Those devices were contracts. A second, and related, point is that

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<sup>14</sup> The first step in this experiment, and the one repeated here, involved 'sister ships' of almost identical design and manufacture. They were broken up in Western Europe by different firms, with different experience, in different locations. The sub-section draws on 20 months' research divided fairly equally across the two sites conducted primarily by Melania Calestani and Helen Watkins. The first project commenced in January 2008 and ended in April 2009; the second ran from September 2008 to August 2009. Data comprises 34 separate periods of observation, and includes a mix of informal conversations and recorded interviews with workers and managers on and off site. The wider experiment has involved business located in Turkey and 'bundle' tendering. 'Bundling' is a common practice in recycling activities. It involves combining 'gold' or 'nuggets' with 'rubbish', in this case a very dirty (i.e. costly to dispose of) vessel and one of greater estimated value.

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the project demonstrated that certain types of vessels cannot be turned sufficiently to profit within this facility.

In contrast, the second project involved new entrants to the market and a dry dock. Although 'hot-cutting' occurs, the primary means to breaking, and to sorting and reducing materials, is through multiple hydraulically-operated shears, working concurrently. Asbestos remediation work again precedes cutting. A dry dock is seen to offer the best guarantee of the environmentally sound management of ship recycling, in that it ensures the environmental containment of wastes. Such facilities therefore are preferred, at least within environmental policy circles. At the same time, a dry dock allowed the project to be cast as a demolition project. Profitability in demolition is related to time/speed of operations, and not – as in recycling – to maximising the extraction and recovery of valuable metals. A final distinction from the first project is that it experimented in realising value through sales into the second-hand re-use and souvenir markets.

A moot point with the second project, as with the first, however, is its commercial success. Three lessons were learnt. First, the project showed that a dry dock is not necessarily the most viable commercial location for ship recycling, since it limits capacity not just to the physical capacity of that dock but to the temporalities of the projects it contains. Further, whilst dry docks in old ship repair yards in 'brown-field' sites may appear prime candidates for ship recycling to planners, policy makers and politicians, long abandoned as working sites many have fallen into states of disrepair. To rekindle such moribund dry docks, and keep them fit for work, requires much by way of costly repair and maintenance and thus further undercuts already tight profit margins.

A second lesson relates to the anticipated means to profitability, time/speed and its connection to the technologies and capacities of cutting equipment. Time/speed estimates were based on knowledge of demolition projects, not ship recycling. They flattened ontological distinctions,

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suggesting equivalences between ships and buildings. The project demonstrated that equivalences could not be assumed. In this instance, operatives skilled in demolishing buildings had to work out how to cut the unfamiliar structure of a ship. At the same time, the vessel itself worked to diminish the capacities of cutting technologies. Thus, in an ironic twist, at the same time as recovering scrap, the affordances between steel and the cutting technologies consumed the shears' 'teeth' at an alarming, and costly, rate, resulting in unanticipated down time for men and machinery. Further, whilst the pace of cutting accelerated through the project, it did so insufficiently fast to realise the levels of profitability envisaged.

A third lesson learnt was that ship recycling is about extracting value from end-of life objects through recovering materials. With an emphasis on the time/speed of cutting, rather than slow(er) cutting and the careful sorting and separation of non ferrous from ferrous metals, this project generated considerably less non-ferrous metal than the first. Mechanised cutting generates ferrous scrap quickly. Putting a large volume of ferrous scrap to market quickly is fine, but only if prices are high, and indeed it was the ferrous scrap high of 2007 that had tempted market entry here. But, at a low point in the scrap metal market, which was the situation for much of this project, rapid volume sales are more questionable as the basis for profitable activity. Further, whilst the retrospective recovery of non-ferrous metals from undifferentiated piles of ferrous is technically possible, through a 'fragger', the costs of so-doing are high; so, in this instance materials present were not recovered but rather dissipated, resulting in value lost. Yet, what was demonstrated was the value to be gained from the extraction of objects for sale in the second-hand and souvenir market. These lessons have been taken on board by the disposal authority, with efforts being made to stimulate the first firm to recognise the implications of their neglect of the re-use market.

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Efforts to stimulate inter-firm learning serve to highlight the location of the two projects within a wider project of economic experimentation. Yet, whilst those who conduct the economic experiment learn inductively, through an analysis of comparative commercial data, a more open question is the degree to which learning is possible for firms. Whilst inductive experimentation within firms establishes that profitability in this market rests on value extraction, ex-naval vessels are bespoke objects not standardised units. Uniqueness means that - for firms - each project is a more-or-less unique experiment in extracting value. This last point is also significant in furthering conceptualisation of economisation. Uniqueness is antithetical to stabilisation, be that commercial, at the level of the firm, or the stabilisation of activities as economic. Further, it signals that objects can be active participants in economisation. Indeed, complex, heterogeneous and unique objects – such as end-of-life naval vessels – are, as we have shown here, multiple; in how they un-become, in what they might become, and in how they are turned to value.

## **Conclusions**

A focus on the economisation and marketisation of the UK's Ship Recycling Strategy allows us to make three points by way of conclusion.

First, the paper has highlighted the difficulties of translating environmental values, grounded in environmental and social justice, to economic value. The details of the case speak more generally. Moral and normative imperatives inform an array of supranational policy interventions that seek to govern global flows in wastes, not just end-of-life ships. Whilst they may recognise the economic logic that generates these global flows and trades, and that wastes transported to another place can become resources, typically little thought is given in both NGO and governance circles as to how to make markets from sequestered end-of-life goods and the activities of their recovery. The economics gets overlooked. In western European countries, such as the UK, the legacy of waste's

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former externalisation combines with high costs of waste remediation work and disposal, which is in turn indicative of economising environmental values. This legacy makes it hard to economise end-of-life goods that contain much by way of hazardous waste, as well as difficult to constitute markets for recyclates. To show just how hard this is, though, requires a turn to Callon; to read recycling activities not just through a governance lens (as is pervasive in the social science literature) or even through standard economic concepts (which still have something to offer) but as economisation.

Second, the paper has demonstrated the importance of assaying and assay devices as calculative devices in the economisation of ship recycling. Assay devices are an important category of market device to place alongside the equations and technological devices that have figured to date in work on economic performativity. The paper has shown how assaying, grounded in surveying, sampling and laboratory analysis and testing, and estimation relate to firms' participation in recycling economies and to disposal agents' experimentation in constituting markets in secondary materials recovery. Here the products of assaying are assembled to constitute assay devices. However, the capacity of these devices to calculate and hence stabilise this instance of secondary materials recovery as a commercial activity has been shown to be partial. This is evidenced by the need to resort to revisiting contracts in the initial phase of the experiment. Contracts not only frame market transactions but also – as here - have the capacity to un-become, to unfold, and to be retrospectively rewritten. They therefore have the capacity to crumple linear notions of economic time. As such, they can perform economic magic, rendering activities that were insufficiently profitable, activities that were commercially viable. Such qualities make contracts vital market devices in politicised markets, such as those seeking to economise secondary materials recovery in parts of the world where the costs of hazardous waste remediation and disposal are high.

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A third point concerns measurement and its connections to the political. In part, the limits to assay devices are generic to measurement: they are, as Barry (2002) has argued, indicative of the uncertainties that surround any form of measurement. But, they are also about the relationship between measurement and economic activity. The task of measurement in ship recycling is not to know with certainty. Rather, it is to estimate sufficiently well such that the calculation of material categorical relations on which economisation rests ensures that economic activity can occur, sufficiently profitably and safely. Measurement in this instance does not purport to know fully these objects and the materials they contain. Rather, measurement is in an instrumental and interior relation to economisation. In such instances, knowing the object and its materials is a task handed over from the sphere of the science-technical to marketisation, whilst participants in the market have the challenge of establishing how to work with, and from, these devices.

The trouble is though that the breaking of former UK naval vessels – even ones that are as similar in type, category and class as it is possible to find – is multiple in its possibilities; or, end-of-life ships are not passive objects. Multiplicity depends on the precise conjuncture of techniques and technologies, materials and materiality within any one project. Materials constitute both stubborn facts and economic possibilities in all this. Uncovering too much asbestos, recovering and extracting not enough non-ferrous metal, and encountering too thick steel, all have an effect on profitability. But equally, there are wider political effects, reiterating Barry's point that calculation is not anti-political but rather that calculation opens up the space for political reverberation.

In this instance reverberation is about potential consequences. Although the advent of the UK's Ship Recycling Strategy suggests that the space for political contestation in UK ship recycling has been closed-down, individual ships suggest otherwise, threatening to unravel as commercial projects and – in their unravelling – threatening to spill over into, or contaminate, politics with

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economics. The possibility of economic failure threatens to contaminate a stabilised politics, whilst the particular case shows that the conduits of contamination associated with measurement work both ways. A reliance on measurement within the activities of secondary materials recovery ensures that recycling as an economic activity is not just political but also that politically 'cold' controversies remain open to the effects of economisation. Nonetheless, the space opened up by the uncertainties of assay devices' estimation has to be closed down, not only for market stabilisation to occur but also to continue to secure the political settlement. The empirical case, then, demonstrates that the economisation of recycling is not solely an economic activity, or even just a matter of inductive *in vivo* economic experimentation, but that it is politically ongoing. Whilst it confirms Çalışkan and Callon's argument that economisation is an achievement, not a given, it shows that recycling's economisation within spatially bounded markets is not of economic activity becoming political but rather always political.

### **Acknowledgements**

The research on which this paper is based was conducted under the ESRC-funded The Waste of the World programme (RES000230007). It benefitted from extensive access to two ship recycling projects and from extended discussion with UK civil servants. Nonetheless, the views expressed here are those of the authors. Nicky Gregson would also like to thank: Catherine Alexander, Mike Crang, Daniel Miller, Lucy Norris and Eric Olund for their comments on earlier versions of this paper; Rob Ferguson for discussions on the distinctions of metrology and assaying; and three referees and the Editorial Board of *Economy and Society* for their generous and stimulating critique of the initial draft. The usual disclaimers apply.

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Table 1: Summary example of hazardous materials (asbestos) as presented in Green Passport  
(Source: Disposal Service Authority)

Type of Asbestos materials (Board, Pipe Lagging, Contained)	Location	Approximate Quantity
	<i>Machinery Spaces</i>	
CAF gaskets	Steam supply piping jointing gaskets	5kg
	Steam exhaust piping and hangers (General)	None known
	Relief & safety valves (General)	None known
	Miscellaneous piping covering and hangers	None known
	Water pipes and hangers (General)	None known
	HP Turbine Insulation (General)	None known
	Boiler drums and casings (General)	None known
	Heaters, Tanks etc (General)	None known
	Other (General)	None known
Amosite board panels	Port and Starboard funnel spaces	400m <sup>2</sup> , 50mm thick
Compressed Chrysotile	Electrical spark chutes	10kg
	<i>Accommodation</i>	
	Sanitary & Messdeck spaces (General)	See steam pipes, below
	Interior decks – including underlay (General)	None known
Chrysotile pipe wrap	Steam & exhaust pipes Mess and passageways	2000 metres
	Refrigeration pipes (General)	None known
	Air conditioning ducts (General)	None known
	Cable transits (General)	None known
	External bulkheads (General)	None known
	Internal bulkheads (General)	None known
	External deckheads (General)	None known
Chrysotile board	Internal deckheads – above many light fittings	4000kg

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	Decks adjoining machinery spaces (General)	None known
	Other (General)	None known
	Specific accommodation locations	
	All messdecks steam pipes & electrical heaters	4000kg
	<i>Deck</i>	
	Steam supply piping (General)	See below at specific
	Exhaust piping (General)	None known
	Tank cleaning piping (General)	None known
	Stripping pump (General)	None known
	Other (General)	None known
Chrysotile weave	Fire curtain – tank deck	10000kg
	Specific deck locations	
Chrysotile Pipe Wrap	Steam heating to fire hydrants	Possible – 10kg
	Machinery	
Compressed pad	Brake linings – Capstan, windlass & davits	Possible – under 1kg
Chrysotile & Amosite	Estimated total in ship	40 tons

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Table 2: An end-of-life ship as calculation: materials, estimation and recovery (Source: field data 2009).

Categories of materials	Estimated (e) (tons)	Recovered (r) (tons)	Difference (r - e) (tons)	% Difference
Aluminium	30	58	28	94
Copper	50	256	206	412
Stainless steel	40	27	-13	-32
Ferrous	6580	6093	-487	-7
Asbestos	20 - 40	43	23 - 3	119