How Firms Will React to Limits on Bio-Physical Flows: An Exploration of Possibilities

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1. Introduction: The Need for Bio-Physical Limits

In 1996 sociologist Stephen Bunker wrote a critique of the then relatively new idea of Industrial Ecology. Bunker stated that "if industrial ecology is to realize the important goals that [its founders] clearly wanted for it, its proponents must learn to think physically, or materially, in global terms that allow for the analysis of local ecological, economic, and social effects. On the other hand, if industrial ecology confuses rates of profit, investment, or employment in a sector with the actual mass of matter that it transforms, it is at risk of serving simply as a putatively scientific system of apologetics and legitimacy for corporations in the sectors with the highest rates of innovation (and therefore of profits) which happen to be at the relatively clean end of the commodity chain" (Bunker, 1996, p.428).

In other words the achievement some form of strong sustainability[1] requires an understanding of the total quantity of the flows between the human economy and the bio-physical world. This observation has recently been explored by both ecologists and ecological economists.

For example ecological economist Philip Lawn concluded that absolute limitation of bio-physical flows was required (Lawn, 2001; Lawn, 2004). His conclusion was based on two ideas: that flows to and from the bio-physical world were already exceeding regeneration rates, and that without absolute limits it would be impossible to prevent total flows from increasing via the rebound effect.

Hans Abauer developed this further, suggesting macro-economic mechanisms by which such limitations might be implemented "almost without a drop in prosperity" (Aubauer, 2006, p.637).

Most recently ecologists and other scientists have been working to improve our understanding of bio-physical regeneration rates, including the regenerative capabilities of eco-system services. Using this new knowledge Johan Rockström et. al., have started the process of defining specific limits to human initiated global bio-physical flows (Rockström & et. al., 2009; Rockström, 2009). Aligned with Lawn and Abauer's conceptual thinking, Rockström et. al.'s work adds quantified absolute limits on human initiated bio-physical flows. This includes specifying limits on the flows of: gases causing climate change and stratospheric ozone depletion; fresh water use; materials causing ocean acidification, atmospheric aerosol loading, and interference with phosphorous and nitrogen cycles; as well as limits on the processes which change land use, increase bio-diversity loss and create chemical pollution.

[1] "The meaning of sustainability is the subject of intense debate among environmental and resource economists. Perhaps no other issue separates more the traditional economic view of the natural world from the views of most natural scientists. The debate currently focuses on the substitutability between the economy and the environment or between 'natural capital' and 'manufactured capital' – a debate captured in terms of 'weak' vs. 'strong' sustainability." (van den Bergh & Verbruggen, 1999). In summary: weak sustainability assumes manufactured capital can substitute for natural capital, strong sustainability assumes this is impossible in all cases.

There are still significant scientific questions which remain to be answered in order to be able to practically implement such limits within the global economy. Further, policy questions of equity and implementation must also be resolved before such limits can be put in place in national economies and the behaviours of firms and households start to change.

In this paper the collection of polices that might be designed to limit bio-physical flows into and out of the economy will be referred to as "limitations policies". As mentioned above, Aubauer started to explore some of the macro-economic issues in setting limitations policies (Aubauer, 2006). However, there appears to have been very little exploration of the micro-economic aspects of limitations policies. This paper's contribution is to start this exploration.

2. Approach

Writing in 1990 John Robinson stated that "more and more the policy agenda is being driven by the need to respond to scientific evidence of serious environmental problems" (Robinson, 1990, p.821). In response he suggested that new methodological approaches were required to explore the "interactions between human and natural systems over time, and analyse the degree to which undesirable futures can be avoided or responded to, and desirable futures created" (p.822).

As outlined above, limitations policies are a clear example of policy being driven by ecological science and ecological economics research. Hence this paper's exploration will use Robinson's suggested methodological response to these challenges: backcasting. Backcasting, is not prediction, but rather an approach to analyse "how desirable futures can be attained" (p.822)[2].

3. Expected Results and Results Summary

By examining the path(s) to the "desired future" it is hoped useful insight can be gained for both firms' management teams and policy makers.

To gain competitive advantage some firms choose to take a first mover approach. For firms' whose management wish to gain such a first move advantage, based on the likely implementation of limitations policies, this paper's analysis re-enforces the importance of pursing existing approaches to improving sustainability approaches.

For policy makers designing limitations policies and their implementation, this paper's analysis highlights some key challenges. Responses to these challenges are suggested for further consideration in the policy design and implementation processes with the aim of increasing limitations policies acceptance and success.

[2] Backcasting is one of a range of methods for exploring and creating alternative futures which includes: modelling, simulation, (participative) action research, scenario analysis, design science and the Delphi technique. Backcasting is explored in detail in both Robinsons original 1990 paper and his 2003 update which describes the key learnings from applying this methodology in the field (Robinson, 1990; Robinson, 2003). Specifically, the backcasting approach is a key part of The Natural Step™ a well know sustainability planning approach for firms (Nattrass, 1999). These authors consider backcasting to be a normative approach, i.e. one that explores an implementable / practical vision of an idealized future. This papers use of the backcasting methodology is aligned with this view.

This paper concludes with recommendations for additional research that would provide increasing specificity and certainty to both firms' management teams and policy makers.

4. Defining the 'Desirable Future'

This paper defines the desirable future as a time, likely a decade or more hence, when limitations policies have been implemented and firms have adjusted strategically and operationally to the limits on bio-physical flows without widespread economic hardship[3].

It is assumed that the implementation process will include a significant transition or implementation period. This will be at least five years, during which the limitations policies will have been articulated in detail but not yet (fully) in place. For example penalties might not be enforced. During this implementation period firms can undertake strategic plans to ready themselves for the effect of limitation policies, and may choose to operationally reduce their bio-physical inputs and output flows as per the articulated limitation policy requirements.

This implementation period will be explored below. However, it is worth stating the micro-economic principle behind it: that costs which are fixed in one timeframe are often able to be made variable in a longer timeframe. i.e. through investment in innovation and sufficient time it is more likely a firm may be able to evolve successfully in response to changing conditions.

Finally, it is assumed that this future can emerge within the broad parameters[4] of the existing global socio-economic system. i.e. modified capitalism operating in a range of political systems with some (limited) oversight from global institutions (UN, WTO, World Bank, etc.).

5. Pathways to the Future

Firms of all kinds emerge, struggle to grow, flourish and cease to exist. The transition from one state to another is driven by a multitude of causes. The backcasting approach suggests it is importance to understanding the possible transition paths. Figure 1 examines three pathways for firms, each with three starting points.

[3] This paper excludes the examination of the impact on households, the other part of the traditional view of the economic system.

[4] There could significant variation in these parameters, which are broadly described by the environmental sociology approach of "ecological modernization" (Hannigan, 2006,pp.25-28). For examples of possible significant changes to current typical macro-economic and social policies see examples by Lawn, Jackson et. al., Sorrel and Victor (Jackson, Daly, Speth, & Korten, 2011; Lawn, 2010; Sorrell, 2010; Victor, 2008, ch.11).

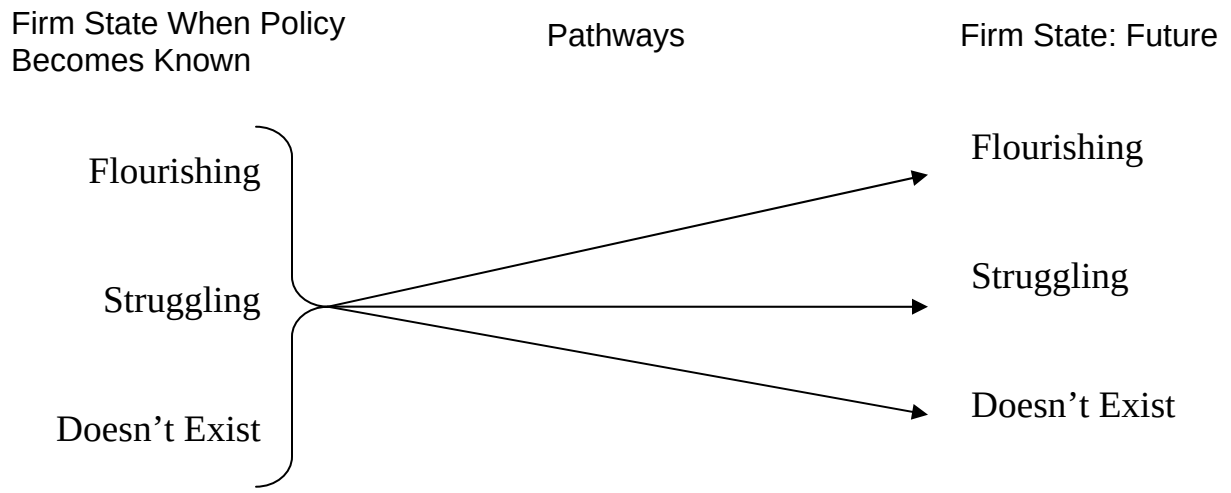

Figure 1 – A Backcasting Framework for Analysis: Pathways to the Future

At the time limitations policies become known to any specific firm, the firm could be in one of three states defined based upon the firms own understanding of its success: flourishing, meeting or exceeding all elements of success; struggling, failing to meet one or more elements of success; or not yet in existence (i.e. the conditions don't exist for the firm to be successful).

At some point in the future, once the limitations policies are implemented and firms have had some time to adjust their strategies and operations, firms will end up in one of the same three states: flourishing, struggling, or they will no longer exist.

Following the backcasting approach, examining the pathways shown on figure 1 leads to the identification a number of questions about how the desired future, where firms have adapted without widespread economic hardship, might be achieved. Table 1 shows the questions this paper will consider along with potential perspectives on these questions from the firm management and policy maker perspective.

Pathway Question	**Possible Firm Management Perspectives**	**Possible Policy Maker Perspectives**
1. Will any firms continue to exist in the future state?	If no firms are likely to survive: How can we prevent limitations policies from being implemented?	If no firms are likely to survive: Are there alternatives to limitations policies which would yield the bio-physical benefits without the economic disadvantages?

Pathway Question	Possible Firm Management Perspectives	Possible Policy Maker Perspectives
2. What could help a firm flourish in the future state?	How can we best adapt? What will be involved? What resources will be required (human, financial, knowledge, material)	What aspects of a limitations policy and its implementation plan influence a firm's ability to adapt and subsequently flourish?
3. How can the number of firms struggling or ceasing to exist be minimized in the future state?	How can we manage the risk?	Can safe guards and / or incentives be included in the policy and/or its implementation plan to minimize the number of firms which struggle or cease to exist?

Table 1: Questions Concerning Pathways

The rest of this paper will explore possible answers to these questions before concluding with a discussion on implications for firm's management, for limitations policy designers, and a discussion of the gaps in this analysis, including suggestions for applicable future research.

6. Will Any Firms Continue to Exist in the Future State?

The historical record suggests that firms don't survive for long periods of time. For example OECD data suggests around 60% of firms in the manufacturing and service sectors in 6 of the larger OECD countries cease to exist within 7 years of founding (Organization for Economic Co-operation and Development (OECD), 2001, p.14, Figure VIII.5).

Thus in this exploration care needs to be taken to separate some (significant) background rate of firms ceasing to exist for a wide variety of reasons, from firms failing because of the implementation of limitations policies.

The same report suggests that it is new and not existing firms that "provide a relatively larger contribution to multifactor productivity improvement, possibly because they enter the market with a more 'efficient' mix of capital, labour and likely new technologies" (p.3). This suggests that productivity within (ever) changing conditions is enhanced through the creation of new firms and less by the evolution of the capabilities of existing firms. Thus, for the policy maker, though not for the members of individual firm's management teams, care needs to be taken not to overstate the importance to avoiding economic hardship on the failure of a certain number of firms.

The above suggests that perhaps the more important pathway in figure 1 concerns the creation of new firms which are designed from the outset with the limitations policies in mind.

For the other two pathways in figure 1, related to existing firms, limitations policies might appear to be something new: preventing the purchase of certain inputs or disposal of certain outputs above certain physical limits. If limitations policies are indeed something new, as yet un-experienced by firm's today, it is legitimate to ask whether or not any existing firm's could survive.

At a fundamental level the idea that to meet their needs humans collaborate, and that firms are one expression of this collaboration is well understood. It would seem unlikely that all collaboration would suddenly end at the introduction of limitations policies. Indeed some have suggested the reverse: that sustainability requires more interdependence and hence more collaboration. It therefore seems likely that people will use firms to meet more of their communities needs (albeit organized and measured in non-traditional ways) (Edwards, 2005, ch.3).

However, one difference about limitations policies compared to existing regulations would appear to be the number of materials involved, and the centrality of those materials to so many of today's production processes, for example, CO_2 production from fossil fuels or the use of human made fertilizer.

To survive, whether to struggle or flourish, considerable amounts of innovation and change will be required by nearly all existing firms. From a scale perspective this is certainly an unusual and perhaps even historically unique situation given the number of firms needing to simultaneously react to a common change in their environment. This scale aspect will be explored more below.

The question for the moment is will any existing firms survive, not how many nor what might differentiate firms that survive from those that do not.

To provide a perspective on this question consider an example related to limits on one bio-physical input, oil. For the past three years, former energy economist for CIBC, Jeff Rubin, has been highlighting the connection between the future flourishing of firms, households and economies and the innovations required to deal with impending constraints related to oil and gas (Rubin, 2009; Shim, 2011). Although the source of the constraints Rubin discusses is significantly (200-400%) higher prices rather than policy, firms are starting to include elements in their strategies and operations which take the impending limitation on oil based on price into account (e.g. electric cars, renewable electricity generation, organic agriculture). In addition, many of these strategies, sometimes by design other times as a side effect, start to address limitations in other bio-physical flows. For example electric cars have far fewer parts, requiring less material to manufacturer and repair. While no one expects all firms to survive and flourish in an age of dramatically higher oil prices, neither is anyone suggesting the failure of all firms (Edwards, 2005)[5].

[5] The broad range of examples of adoption strategies to challenges such as the reduction in the historically increasing supply of oil is the basis for Andres claiming a revolution is underway and using the term revolution in the title of his 2005 book "The sustainability revolution: portrait of a paradigm shift".

But is the idea of limitations or constraints on the inputs to and outputs from a firm a new idea which somehow calls into question the fundamental ability of firms to survive? Are all of the mechanisms available to firms to adapt to changing circumstances invalidated by limitations policies?

The discipline of micro-economics is often said to be about the efficient allocation of scarce resources to achieve desired benefits for firms and households. This idea explicitly recognizes that economies and economists deal with limitations and constraints of many kinds as a matter of course.

Turning to the micro-economic level, a common textbook for management students is the 1990 "Managerial Economics" by James Pappas and Mark Hirschey. These authors open their first chapter "The Nature and scope of Managerial Economics" by stating "effective resource management is a continuing challenge to managers in all types of organizations" and later go on to state that "in many decision problems faced by managers, there are constraints imposed that limit the options available to the decision maker" (Pappas, 1990, p.1, p.50). This text goes on to describe many methods for understanding constraints and limitations, their permutations, and the optimization of decisions to maximize desired outcomes. Within the topic of limitations related specifically to inputs, Pappas and Hirschey devote approximately 10 pages.

A specific illustration of these theories and practices is Clifford Russell's excellent work on optimizing, based on environmental and economic criteria current in the 1970's, inputs and outputs of a petroleum refinery using linear programming. This work provides a fine example of well understood approaches for management to deal with limits and constraints in the most "efficient and effective"[6] manner (Russell, 1973).

More generally it is clear that firms have to deal with shortages and limits of all kinds at all times: limitations on the quantity of bio-physical inputs and outputs being only one. Other limitations firms routinely deal with include both the quality and quantity of skilled workers, customers, financial capital, regulations, etc. Indeed from the perspective of the decision makers in a firm, a large part of strategy involves understanding the causes of limits and designing approaches that enable the firm's goals to be achieved despite them.

Indeed, so normal has the understanding and acting in light of limitations become that a significant body of management theory, known as the "Theory of Constraints", has been developed and implemented (Goldratt, 1997).

[6] Efficiency and effectiveness are of course relative to the variables being considered. For the purposes of this paper, where it is assumed the achievement of near term sustainability is largely in the hands of the implementation and enforcement of limitations policies, efficiency and effectiveness are relative to the variables society considers important for firms to maintain their social license to operate (Doig, 2003; Hart & Milstein, 2003).

In their book "The Theory of Constraints and its Implications for Management Accounting" Eric Noreen et. al. open their executive summary as follows:

> The core idea in the Theory of Constraints (TOC) is that every real system such as a profit-making enterprise must have at least one constraint. If it were not true, then the system would produce an infinite amount of whatever it strives for[7]. In the case of a profit making enterprise, it would be infinite profits. Because a constraint is a factor that limits the system from getting more of whatever it strives for, then a business manager who wants more profits must manage constraints. There really is no choice in this matter. Either you manage constraints or they manage you. The constraints will determine the output of the systems whether they are acknowledged and managed or not. (Noreen, 1995, p. xix)

It is clear from the TOC that constraints are not expected to stay fixed over time. Of course, the impacts of existing constraints can ameliorated through a vast array of techniques, and so can be lessened in importance over time. But, at the same time, new constraints will emerge as the environment within and outside the firm changes. Within this perspective, the well managed introduction of limitations policies can be seen as just one more changing limitation all firms must deal with to remain successful.

If it isn't the concept of limitations per se that is new, nor the number or centrality of the materials to be limited, perhaps what is new that might cause universal firm failure is that the limitations are on something that was available for a price, but no longer is.

Since the mid/late 1960's there has been a widespread introduction of laws and regulations related to the environment. Many of these have related to the control, reduction or banning the use or emission of materials, i.e. non-price based mechanisms. Firms who will be impacted by such regulations have often lobbied to prevent their introduction or curtail their impact on a firm's existing business model, claiming (at some level) that the firm's existence is threatened by such controls.

However Michael Porter has argued for over 20 years that the reverse is actually the case: well designed regulations can actually enhance a firm's ability to create innovative solutions to over come limitations (Porter, 1991). Indeed, in a 2010 review of the behaviour of firms, NGOs and regulators Porter suggests that considerable progress has been made in the design of regulations to enhance the likelihood that innovations will be created benefiting the firms, the environment and society at large (Porter, 2010, slide 9).

[7] In recognition of Georgescu-Roegen's ideas it must be noted, unlike these writers, that this is a theoretical perspective which of course this could not continue for ever!

7. Possible Firm Level Responses

The above analysis, in response to the first question from table 1, suggests that in principle firms can survive the implementation of limitations policies. If this is assumed, it then becomes important to explore the other pathways show in figure 1 via the second two questions from table 1: what could help a firm flourish (whether it be a new or existing firm) and how can the number of firms struggling or ceasing to exist be minimized as a result of the implementation of limitations policies.

This section first presents a number of strategies which have been theorized and tested to varying degrees which start to answer these two questions. The section concludes with an exploration of firms and organizations who to some extent have decided to voluntarily limit their bio-physical inputs and outputs to see what their collective experience might contribute.

Before exploring micro-economic (i.e. firm specific) strategies it is important to understand some of the macro-economic context and implications of limitations policies.

One likely impact of limitations policies is that the average growth rate of the economy, and certainly that part of the economy based on material use, will slow to zero and possibly become negative for some period of time. Ecological modernization generally assumes that there will be no explicit restrictions on individual firm growth through existing market mechanisms (Hannigan, 2006,pp.25-28). However, the restriction on the availability of inputs and the ability to create certain outputs may mean it is harder for as many firms to flourish.

However, as today, there will continue to be individual firms that innovate their way far above average. Further, in as much as such innovations can be achieved without incremental bio-physical inputs or outputs, any firm whose strategy is based on such an approach would yield growth in that firm's revenues based on increasing exchange value within the economy. This strategy is explored in more detail below.

The historical perspective is also potentially instructive: are the types of changes firms need to make to accommodate limitations policies novel? Is there historical precedent? As one example: in his 2007 paper Pierre Descrochers makes a convincing argument that firms have consistently used multiple strategies to flourish through the proactive minimization of by-products (waste) since early in the industrial revolution:

> Market institutions, which included both profit motive and property rights, [] resulted in the usage of industrial by-products. Although past industrial activities did create significant pollution problems, perhaps our ancestors should be given more credit than they generally are for the creativity and resourcefulness they displayed in profitably solving numerous environmental problems (Desrochers, 2007, p.348).

With these overall perspectives in mind, below are presented a number of strategies that could help firms flourish within the types of conditions limitations policies will create as well as a discussion of some of the challenges which firms may face.

Strategy: Innovation

Earlier the idea was introduced that managing within constraints is a normal part of any firm. This begs the question: how do organizations "overcome", "deal", "work-around", "exploit" and indeed "flourish" in a normal world full of ever changing constraints?

One answer which is frequently discussed in the management literature is the role of innovation. Michael Hammer defined "true" innovation as entailing "anticipating the opportunities for meeting latent need, for solving problems that customers may not even recognize that they have" (Hammer, 1996, p.99). Hammer suggests that it is innovation of all kinds (technological, knowledge, skills, practices, processes, etc.) within an individual firm which will allow it to flourish sustainably despite shifting constraints.

Clearly, as limitations policies are likely to require significant reduction in bio-physical inputs and outputs, a significant amount of innovation will be required by all firms.

In his widely cited 1996 article, Eric Kessler and Alok Chakrabarti propose a conceptual model of the context, antecedents and outcomes of the speed at which a firm is able to innovate (Kessler & Chakrabarti, 1996). The authors make a significant assumption that innovation speed is positively related to both the quantity and quality of the innovations generated by a firm. However, despite this, their model appears instructive when considering how to design the process of changing a firm in response to significant external changes, such as limitations policies.

Of the 13 antecedents to improving innovation speed identified (p.1155) knowledge and / or skills can be said to form a key part of 9 (goal clarity, project support, project stream breadth, external sourcing of skills and knowledge, leader strength, team member experience, team representativeness, project integration, process organization). Further underlying all of these is the need for knowledge related to any and all alternative approaches which need to be considered in response to limitation policies.

The importance of skills and knowledge to successful, timely innovation implies a huge volume of new knowledge and skills will be required by a very large number of people. This suggests that sourcing this knowledge will be key to firms thriving. These implications for limitations policy design and implementation will be considered more later.

More specifically, there is a significant amount of research which suggests innovative strategic and operational approaches firms can take along a number of dimensions to achieve flourishing sustainability.

By way of example, firms looking to adapt to limitations policies could improve their likelihood of thriving by leveraging the following research:

Sustainability strategy and business models

- Strategic advice for firms looking to flourish in a post-growth economy (Speth, 2009) and manage the required transition (Speth, 2008)
- Application of the Resource Based View theory of firm competitiveness to environmental performance (Russo & Fouts, 1997)
- Exploration of sustainability business strategies (Stead, Stead, & Starik, 2004) and sustainability business models in Nordic countries using the Theory of Constraints as a framework (Birkin, Polesie, & Lewis, 2009).

Firm level measures of sustainability

- The ability to measure and track progress towards sustainability goals is critical to firms' management team's ability to efficiently and effective manage the transition. Isabelle Callens and Daniel Tyeca propose a set indicators which can be "used as an aid to detect factors of unsustainability, and hence to provide for recommendations as to [] management practices that will contribute to overall sustainability" (Callens & Tyteca, 1999, p.41).

Changing relationships amongst value system members

- Firms exist as part of complex systems of other organizations and individuals. Historically many of these relationships have been primarily economic, with each player competing to minimize their own cost in order maximize profitability. Recent supply chain research by Mark Pagell and Zhaohui Wu suggests that these historical approaches yield less sustainable outcomes in the long term and explores more sustainable approaches to relationships that are starting to emerge (Pagell & Wu, 2009; Pagell, Wu, & Wasserman, 2010).

Frameworks for understanding and optimizing the transition process

- While numerous change management frameworks and methodologies exist few are explicitly targeted at organizations attempting to transition to improved levels of sustainability. An exception is the Efficiency, Substitution, Redesign frame work by Stuart Hill and Rod MacRea. This provides a "guided maturity model"[8] for management to understand and plan how quickly and completely they should / can transition to more sustainable operations (MacRae, 1991).

[8] Personal communications with one of the authors Rod MacRea.

Strategy: Closed Loops

Given the materials focus of limitations policies any strategy firms can take which minimizes the impact of materials shortages without circumventing the policy could be helpful.

One such strategy which is widely discussed in the sustainability literature is the idea of closed loops. In this approach, inspired by the idea that in nature nothing is wasted, firms strive to ensure that all material inputs can be obtained by reusing the firm's outputs.

In their 2002 book Cradle to Cradle William McDonough and Michael Braungart suggest that firms need to consider two closed loops related to materials: one for what they refer to as "biological nutrients" and one for human made or "technology nutrients" (McDonough, 2002, pp.103-115). Using this approach firms could reduce their need to change processes which depend on availability of materials restricted under limitations policies by sourcing or sinking these materials within the closed loops suggested by McDonough and Braungart.

In a sense closed loops are just one example, albeit a key one, of innovation at the systems rather than the individual firm level. Other works which provide examples of design processes and / or highlight examples of systems level thinking which could help firms flourish include:

- Works commissioned by the Club of Rome, the books Factor Four and its update, Factor Five, provides numerous examples of 75% and 80% reductions in material and energy use using existing and mostly proven technologies (Weizsäcker, 1997; Weizsäcker, 2009). Many of these examples are the basis of claims by Al Gore and others that the technologies required to achieve most (all) of the IPCC recommendation on green house gas and other emissions already exist (Guggenheim, 2006).
- Works which explore adopting processes and structures found in nature in industrial production processes include the books Biomimicry (Benyus, 2002)and Green Chemistry (Anastas, 1998). Adapting the ideas in these books to their specific situations, firms can significantly reduce thier inputs of materials and energy and outputs that harm eco-system services, humans and other species.
- Works which explore systems approaches to understanding and designing, such as John Stermans book Business Dynamics (Sterman, 2000) and The Natural Edge Project's Whole Systems Design (Stasinopoulos, Smith, Hargroves, & Desha, 2009).

Strategy: Focus on the Things That Can Grow Sustainably

In his 2008 book "Managing Without Growth" Peter Victor notes that as long as an activity is decoupled from material throughput and land-use it should be able to continue sustainably (Victor, 2008, pp.184-185). Jonathan Harris in analysis presented in his 2009 paper provides more detail on the economic categories of activities which have a true net economic benefit (i.e. including the economic costs of the environment and society). Acording to Harris these include: public health, well-being support for the elderly, education, environmental protection, and clean energy development (Harris, 2009, p.43). One characteristic of these activities is that they generally have a high labour component and a lower materials component when compared to other classes of economic activity.

Certain strategies firms have historically used to overcome limitations, such as material and energy efficiency improvement, have often led to increases in the total materials and energy used in the economy (via the rebound effect). One of the objectives of limitations policies is to prevent such increases; hence these historically successful strategies will no longer be available to firms. Thus some firms existing business models may be invalidated by limitations policies and there may be no valid technological innovation.

Bringing these observations together suggests that firms seeking innovative approaches to improving their sustainability may wish to consider radical transformations using Harris's insight as a basis for a sustainable business model rather than struggling or ceasing to exist.

Examples of Firms Voluntarily Limiting

There are a small (but increasing) number of firms and organizations which are proactively innovating to reduce their reliance on bio-physical flows and hence increasing their sustainability. These firms are in a sense voluntarily choosing to operate as if limitations policies of some type were already in place or will be implemented at some time in the future.

The motivations for firms to make this choice appear to fall into two groups: those firms whose owners see a moral requirement to improve their sustainability, and those firms who believe risks to their ability to continue to operate "business as usual" now exceeds the risk of the (substantial) changes required to improve their sustainability.

It seems probable that firms who voluntarily adapt and subsequently flourish will be creating the strategies and operational processes which the majority of firms could use to flourish once implementation of limitations policies are implemented. Many of the suggestions made earlier have come directly or indirectly from such firms' experiences.

Indeed, some might argue that the majority of firms who take no action will have an easier time later, since the limitations policies will apply equally to everyone, and hence issues such as changed cost structures will apply to all market players not just those who have volunteered.

Further it also seems probable that additional study of these volunteers could be instructive for policy makers to help make the design and implementation of limitations policies more successful.

A few examples of leading firms include:

- Collins Co. a Forestry Stewardship Council certified lumber company whose founder, Truman W. Collins, stated in at the firms founding in 1943 "our mission is to manage the forests sustainably. Nurture the forest's biodiversity. Help create a stable workforce that builds healthy communities where families can work and flourish. Foster loyalty and trust simply by being loyal and trustworthy. Leave the Earth better for our being here". Today this vision is operationally realized by limiting wood product production to the re-growth rate of the forests which the firm owns. In effect Collins has already innovated to successfully operate within (self-imposed) limitations policies. http://www.collinsco.com/
- Interface Flor http://www.interfaceflor.com/ whose very well known 10+ year journey includes innovation to overcome self-imposed constraints of bio-physical resource use and waste generation
- Many of the 20,000 members of the Business Alliance for Local Living Economies (BALLE) http://www.livingeconomies.org/
- Many of the 381 certified B-Corporations who have voluntarily (and increasing legally[9]) agreed to "constrain" their operations by all three dimensions of sustainability, and hence, at least to some extent reduce their bio-physical inputs and outputs http://www.bcorporation.net/.
- Many of the several dozen firms described by Jill Bamberg in her recent book "Getting to Scale – Growing your business without selling out" (Bamberg, 2006).
- Many of the firms undergoing various third party certifications, such as Forestry Stewardship Council, Marine Stewardship Council etc., as described in Michael Conroys 2007 book "Branded! How the 'certification revolution' is transforming global corporations" (Conroy, 2007).
- Many of the firms involved in industrial symbiosis, aka eco-business zones or eco-industrial parks around the world.

[9] B-Labs objective is to create a new kind of corporate legal entity which legally enables boards of directors and management teams to optimize on all three dimensions of sustainability, rather than only economic (as with all existing corporate legal entities). Already two US states (Maryland and Vermont) have past such enabling legislation and 11 more are looking to pass the required acts in 2011. http://www.bcorporation.net/publicpolicy. B-corporation formally launched its campaign in Canada in 2010. 12 of the certified B-Corps are Canadian. Information retrieved from http://www.bcorporation.net March 1, 2011.

8. Implications for Firm's Management

From the above exploration of how firms could react to limitations policies it appears that in general firms' management teams should draw some comfort. While the strategies explored above have some novel ideas, drawn from outside existing management literature, in general it seems firms are being well equipped by academia with a range of useful theoretical models and by practitioners with significant experience to deal with, and indeed flourish, within the constraints of limitations policies.

Firstly, much of our existing knowledge, summarized above, of how to operationally overcome constraints will still be directly applicable or applicable with minor changes to enable firm flourishing under policies designed to achieve strong sustainability. For example there is considerable experience with increasing firm's efficiency and effectiveness of materials use which remains applicable.

Secondly, the increasing numbers of volunteers are demonstrating, even under existing market conditions and uncertainty about whether limitations policies will be implemented, that thriving is possible while increasing adherence to limits on key bio-physical flows. It seems probable that for these firms all that will change, once limitations policies are put in place, is that the primary driver for such innovation will switch from today's self imposed constraints to tomorrow's "hard" bio-physical policy limits.

For many of these volunteers it is the perception of increasing risk to business as usual which is driving shareholders and other stakeholders to demand action by management teams. As usual the understanding of the risks by any population follows some sort of a curve, and hence there will always be leaders and laggards. Indeed, one of the assumptions behind the need for limitations policies is that such stakeholder driven management actions will be too slow and too little to prevent (significantly) over stepping planetary boundaries.

Perhaps the most significant implication of this analysis is to strengthen much of the existing strategic advice to management teams concerning innovation and leadership. In as much as innovations can be achieved within shrinking bio-physical inputs and outputs, any firm whose strategy is based on such an approach could flourish. As Geoffery Moore, in his well known 2002 management book "Living on the Fault Line" stated "to navigate such a transition, it must be driven by timely, unambiguous intervention from the top down. In those cases management must make itself highly visible and act courageously outside the organization's familiar norms to reposition it onto the next wave" (Moore, 2002, p.259).

9. Implications for Limitations Policy Design and Implementation

In his 2001 book "Materials Matter: Toward a Sustainable Materials Policy" Kenneth Geiser sets out to "consider what private and public policies could most effectively guide" "materials development that might be more conductive to health and environmental protection" (Geiser, 2001). This analysis is made within the context of the history and future development of industrial materials (i.e. technical nutrients) and includes significant advice applicable to limitations policy makers in the section entitled "towards a sustainable materials policy" which includes chapters on "dematerialization", "detoxification" and "a sustainable materials economy".

From Geiser's and the analysis above the following implications for policy designers can tentatively be drawn:

First, it must be remembered that with or without limitations policies in place, most firms do not flourish over long periods of time. Therefore care needs to be taken in measuring the implications of limitations policies on firm success and failure rates to ensure any change in firm failure rates is caused by the introduction of limitations policies.

Second, since there also continues to be a large number of firms in existence at any point in time, it implies that large numbers of business are also being created. This suggests that limitations policy designers need to consider how to spur the creation of firms whose business models take the constraints of limitations policies as a normal aspect of their operation from day 1 of a firm's existence.

It would seem that limitations policies designers should consider the relevance of existing policies that are designed to spur the creation of new firms, such as "business incubators" and focusing regional investment policies on specific industries (such as components of the 2009 Ontario Green Energy act).

Thirdly, it is normal for existing firms to have to innovate around constraints of all kinds in order to survive and flourish. Today firms do manage to over come input and other constraints day in and day out under conditions of market uncertainty. As prices and availability of inputs fluctuate, as alternative inputs become available, as new techniques and regulations emerge, firms are constantly innovating to flourish despite these ever changing constraints.

It is also normal for firm's founders to have to innovate in some fashion in order to come up with and execute the business model of a new firm

However, it is unclear what the impact on firm flourishing will be given that the innovation requirements of limitations policies will be imposed on so many new and existing firms at the same time. Could the scale of the innovation required in the same time materially impact individual firm's ability to innovate?

As mentioned earlier, researchers such as Michael Porter, have recently reported on the design of regulations to enhance the likelihood that innovations will be created (Porter, 2010, slide 9).

However, specific work is required to determine what might be the most effective approaches to spurring the creation of limitations policy constrained firms.

Another aspect of the scale of innovation required which it appears policy designers will need to pay attention to is the importance of skills and knowledge to successful and timely innovation. In the case of limitations policies, given the centrality of the materials being limited to existing business models, it would seem to imply that a huge volume of new knowledge and skills will be required by a very large number of people in similar timeframes. In turn this suggests that sourcing this knowledge will be key to firms flourishing.

How might policy designers help to ensure enough of the right kinds of skills and knowledge are available to firms to increase the likelihood of successful innovations in response to limitations policy constraints?

One approach would be to consider the need for significant investment in research, education and training, as part of the limitations policy implementation process. This would imply an increase in the scale of the education infrastructure, and as such, needs to be subject to the limitations policies if it isn't to subvert the limitation policy objectives. As such, one hopes this isn't a catch-22 situation, and clearly further research is required.

Another approach would be to look to sources of knowledge and skills which have been traditionally undervalued or ignored by firms. For example Stuart Hart and Sanjay Sharma suggest non-traditional sources of knowledge may offer firms considerable opportunities to innovate (Hart & Sharma, 2004). Limitations policy designers might consider how they could encourage firms to consistently consider and use such knowledge sources.

Fourthly, there is the increasing number of firms and organizations voluntarily choosing to constrain their operations based on reducing one or more bio-physical flows. It would seem that there could be considerable lessons for limitations policy designers from these organizations. However, there currently appears to be limited research on these organizations that is focused on providing applicable knowledge to limitations policy designers.

Fifthly, to conclude this section, from the positive outlook of ecological modernization which has served as a basis for this papers analysis (Hannigan, 2006,pp.25-28), limitations policy designers should feel optimistic. In principle, limitations policies are not only realistic, but will have innovation benefits in addition to the environmental benefits of limiting key bio-physical flows.

However, even with appropriate planning for significant investment in research, education and training, as part of the limitations policy implementation process, it seems unlikely that every firm will manage to overcome the specific constraints which arise as a result of the limitations policies. Indeed it seems prudent to expect a higher rate of firm failure than is typical while the innovations required to over come the specific constraints of limitations policies work through the knowledge economy. Further such failure rates could vary dramatically by industry sector, given the highly variable dependence on the flows being limited in different sectors. As a result it would seem wise for limitations policy designers to also consider other policies (such as

guaranteed income polices) to minimize economic and social hardship during the implementation process.

10. Further Research

Based on this analysis it appears reasonable to conclude based on current knowledge that in principle limitations policies could be implemented without widespread economic hardship.

However, as noted in the introduction, at the macro-economic or global level, significant scientific and policy work is still required. From the perspective of understanding the impact on individual firms perhaps the key item of knowledge that is currently unknown is the likely size of the reduction in the flows of materials individual firms will experience in order to meet the identified global bio-physical limits. The impact of the size of the reduction of flows on firms' ability to flourish will also depend on the duration and other aspects of the limitations policy implementation period.

In turn this means that understanding likely scenarios of firm flourishing and failure rates given specific limitations policy design and implementation plans is difficult. This knowledge is critical to policy design and ultimately gaining political buy-in. For example, if in a given period of the implementation process a significantly higher number of firms fail than is historically normal, or if significantly fewer firms fail to be launched and / or flourish, this could easily create significant economic and social hardship. Policy makers need scenario knowledge to help to understand these possibilities, try and avoid them if possible, and have contingency plans ready.

This paper, applying the backcasting methodology, has started to identify some of the possible antecedents to firm rates of failure, creation and flourishing under limitations policies. A necessary next step would seem to be to explore how these antecedents could be impacted by various choices which implementation policy designers could make related to policy implementation and operations. Specifically it will be important to understand how these antecedents on firm flourishing impact different industry sectors whose dependence on bio-physical flows vary significantly.

One approach to this exploration could be the development of systems dynamics simulations, perhaps with industry sector sub-models aggregating to a national or global economic view. Such models would allow policy designers to understand the possible impact of various limitations policy and implementation plan designs and the relationships between the different policy and implementation levers. Such a model could be built on Peter Victors Low Grow model (Victor, 2008) or through a collaboration with Reolof Boumans et. al.'s and their GUMBO model (Boumans et al., 2002).

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