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Intergenerational Fairness and the Crowding Out Effects of Well-Intended Environmental Policies

Richard A. Hunt and Bret R. Fund

Virginia Polytechnic Institute; University of Colorado

ABSTRACT Sustainability involves the drive to ensure intergenerational fairness. However, the results of actions taken to achieve sustainability often lie far into the future and efforts to promote the welfare of distant generations may or may not ultimately be successful. While both governmental policies and entrepreneurial innovation have been cited as being indispensable to the achievement of sustainability, the manner in which they co-exist and interact over very long periods of time remains unclear. Using a computational model spanning more than two centuries, this study asks: Do well-intended environmental policies facilitate or inhibit environmental entrepreneurship? By simultaneously considering both the ethical and economic consequences of efforts to arrest environmental degradation, our study answers the call to develop multi-disciplinary perspectives and integrative frameworks when addressing the challenges of sustainable existence. Contrary to widely held perceptions, our findings suggest that policy actions may, in the long run, result in less intergenerational fairness by crowding out environmentally desirable innovations and organizations. Our examination of the long-term interactions between policies and markets offers insights and opportunities for scholars, entrepreneurs, environmentalists, ethicists and policymakers to develop solutions that preserve and extend the essential contributions of both policy actions and entrepreneurial innovations.

Keywords: crowding out, environmental entrepreneurship, intergenerational fairness, sustainability

INTRODUCTION

The ethical underpinnings of sustainability hinge on the concept of intergenerational fairness (Pezzey and Toman, 2002, 2005; Weiss, 1990; Woodward, 2000); meaning that each successive generation harvests renewable resources, depletes non-renewable resources, and generates waste in a fashion that can continue indefinitely (Daly, 1990).

Address for reprints: Richard A. Hunt, Virginia Polytechnic Institute, Pamplin College of Business, Blacksburg, VA 24061, USA (rickhunt@vt.edu).

Given the complexity of the sustainability challenge, arguments have been advanced that a meaningful approach must include aggressive activation of public policy (e.g., Porter, 1991) and resolute enforcement by institutions through international coordination (e.g., Pezzey and Toman, 2005). Scholars have also convincingly asserted that innovating entrepreneurs play a vital role through the agile pursuit of novel solution sets, facilitated through an open arena of competing technologies and business models (Anderson and Leal, 2001; Baumol and Oates, 1988). What is less certain, and what has not been fully assessed, is the manner in which environmental policies and environmental entrepreneurship either coalesce or collide in the marketplace (Dean and McMullen, 2007; Hall, et al. 2010). While calls for transnational (Haas et al., 1993; Susskind and Ali, 2014) and transgenerational (Padilla, 2002; Weiss, 1990) polices have continued to gain momentum, the impact of policy on entrepreneurial action remains largely indeterminate (Anderson and Leal, 2001). If such policies unwittingly reduce the development and commercialization of impactful entrepreneurial innovations (Anderson and Huggins, 2008), then future generations may actually be worse off.

The purpose of this paper is to assess the extent to which well-intended environmental policies facilitate or inhibit environmentally desirable entrepreneurship. Our contributions are fourfold. First, we develop and test the first expansive model that is able to predict how and why environmental policies impact environmental entrepreneurship. While existing literature, primarily emanating from environmental economics (Jennings and Zandbergen, 1995; Newell et al., 1999; Popp, 2010) and corporate social responsibility (e.g., Bansal and Roth, 2000; Hoffman, 1999; Shrivastava, 1995) has related public policy to corporate behaviours by incumbent firms, there are no predictive frameworks regarding environmental policies that fundamentally change the incentive structures (Baumol, 1993) and property rights (Anderson and McChesney, 2003; Bromley, 1991) impacting new generations of innovating entrepreneurs.

Second, our conceptual framework contributes much-needed multi-disciplinary substance to the study of intergenerational fairness. Our approach reconciles and integrates prior efforts to address sustainable existence from solely an ethical or economic perspective by adapting economics-based perspectives on environmental degradation (Jaffe and Palmer, 1997; Newell et al., 1999; Popp, 2006, 2010) and crowding out (Ahmed, 1986; Aschauer, 1985; Barro, 1987) to innovation management-based theories on path dependency (Arthur, 2007; Dosi, 1982; Teece, 1986), and business ethics-based perspectives on intergenerational fairness (Padilla, 2002; Pezzey and Toman, 2002, 2005; Weiss, 1990; Woodward, 2000).

Third, we contribute to the range and sophistication of methodologies that scholars can employ when assessing the consequences of complex interactions that occur well into the future, such as those that characterize sustainability. Using a mathematical simulation, we are able to account simultaneously for the intergenerational effects of both policy-based and market-based efforts to arrest environmental degradation. Although computational modelling has witnessed extensive use in other fields (Hartmann, 2009), it is less common in management research (Harrison et al., 2007). The viability of using our model to integrate sustainability, ethics and entrepreneurship underscores and validates its importance as a complement to more mainstream tools, by providing an intermediation of research that is purely theoretical or empirical (Markman et al., 2015), especially across very long timeframes.

Finally, we inject the critical dimension of time into the study of sustainability, ethics and entrepreneurship. By focusing on far longer timeframes than prior research, our approach invites a fuller assessment of the time-varying interactions between public policy and environmental entrepreneurship. Through this, we offer a clearer picture of the trade-offs that accompany public and private efforts to address the intergenerational impacts of resource depletion and environmental degradation.

In the following section, we discuss important ways in which the scholarship on entrepreneurial action can be more aptly reconciled with the literatures on sustainability and the ethics of intergenerational fairness. We then develop a new framework and derive four propositions that are explored using a computational model. We conclude with a discussion of implications from our study for policymakers, scholars and environmental entrepreneurs.

THEORETICAL DEVELOPMENT

Central to the aims of both well-intended environmental policy and environmental entrepreneurship is the recognition that sustainability involves taking steps to address 'intergenerational fairness' in the actions society takes regarding finite resources and the quality of life available to future generations (Padilla, 2002; Pezzey and Toman, 2002, 2005; Weiss, 1990; Woodward, 2000). Policies aim to affect change through institutional sanctions and supports, actions that typically take the form of subsidies for desirable but uneconomical goods and services, or taxes imposed upon practices and technologies that are environmentally undesirable. Environmental entrepreneurship – which is defined by Dean and McMullen (2007, p. 58) as 'the process of discovering, evaluating, and exploiting economic opportunities that are present in environmentally relevant market failures' – aims to develop and implement technological, organizational and financial innovations as market-based responses to the mispricing of intergenerational impacts. Far from being mutually exclusive, government policy and entrepreneurship not only coexist (Lenox and York, 2011), but also significantly influence one another's ability to address intergenerational fairness (Dean and McMullen, 2007).

Developing and commercializing novel technologies (Popp, 2010) and business models (Zott et al., 2011) through entrepreneurial action is complex and fluid. In the context of policy-driven commitments to specific technological and organizational paradigms, a complex mixture of cooperation and competition emerges involving, on the one hand, the fluid conditions characterizing entrepreneurial innovation and rent-seeking; and, on the other hand, the aims of governmental policy measures that are intended to arrest environmental degradation (Popp, 2010). Our investigation focuses on two effects that are central to the shared fate of sustainability, entrepreneurship and intergenerational fairness: crowding out and path dependency.

Crowding Out Effects

The study of crowding out effects originated in macroeconomics and refers to the phenomenon in which the market participation of one party reduces or eliminates the participation of one or more other parties (Atiq, 2014). Research concerning crowding out has examined it as a potent force affecting charitable giving (Abrams and Schitz, 1978), social welfare programmes (Kenworthy, 1999), education vouchers (Hoxby, 1996), foreign direct investment (De Backer and Sleuwaegen, 2003), technological innovation (Czarnitzki and Fier, 2002), research and development (Lach, 2002; Lööf and Heshmati, 2005), and venture capital investing (Wallsten, 2001). In each of these contexts, crowding out results in a substitution effect as the participation of one party (often government, but not necessarily so) fundamentally changes the incentive structure so that one or more other parties partially or wholly withdraw from participation.

Crowding out effects in environmental entrepreneurship occur when government policies compete with entrepreneurs for the profits associated with solving the market failure of externalities. Externalities from the consumption of environmentally undesirable products arise when costs are created that must be borne by future generations (Dean and McMullen, 2007). For example, present-day consumption of non-biodegradable plastic bottles or coal-generated electricity imposes costs on succeeding generations, people who gain no benefit from the original consumption, but still bear the long-term environmental burdens. In terms of both financial costs and quality-of-life considerations, negative externalities stemming from the consumption of environmentally unsound goods violate the principle of intergenerational fairness.

To the extent that entrepreneurs can commercialize alternatives to environmentally undesirable goods, such as plastic bottles and coal-generated electricity, they can simultaneously derive profits from the solution and advance the cause of intergenerational fairness. Resolution of negative externalities has been cast not only as ethically responsible (Barrett, 1996) but also entrepreneurially lucrative (Coase, 1974; Dean and McMullen, 2007). The financial returns that environmental entrepreneurs can harvest through their innovations is directly related to their ability to resolve the externality problem (Baumol, 1993; Dean and McMullen, 2007). However, when governments implement policies to address degradation, this calculus changes. Since well-intended environmental policies also aim to address the negative externalities associated with degradation, they inevitably impact the payoffs to innovating entrepreneurs who are developing market-based solutions to resolve those same externalities (Anderson and Leal, 2001). Even though the goal of subsidies and taxes is to safeguard the environment, not generate financial profits, the unintended effect is that the payoffs to entrepreneurial innovation are partially or wholly eliminated (Anderson and Huggins, 2008; Popp, 2010).

Traditionally, policy actions have assumed two forms: subsidies for environmentally desirable products, or taxes upon environmentally undesirable products. A stylized representation of policy impacts upon entrepreneurial innovation is captured in Figure 1. The depiction involves policy action that creates a 'zero-profit' condition for breakthrough innovations, meaning that an entrepreneur cannot earn a risk-adjusted return for resolving a negative externality. This occurs because the subsidy or tax already addresses the externality, so that entrepreneurial innovations are economically indistinguishable from existing technologies.

As Figure 1 illustrates, the generation of entrepreneurial innovations involves the confluence of an entrepreneur's propensity to act and his or her ability to produce a

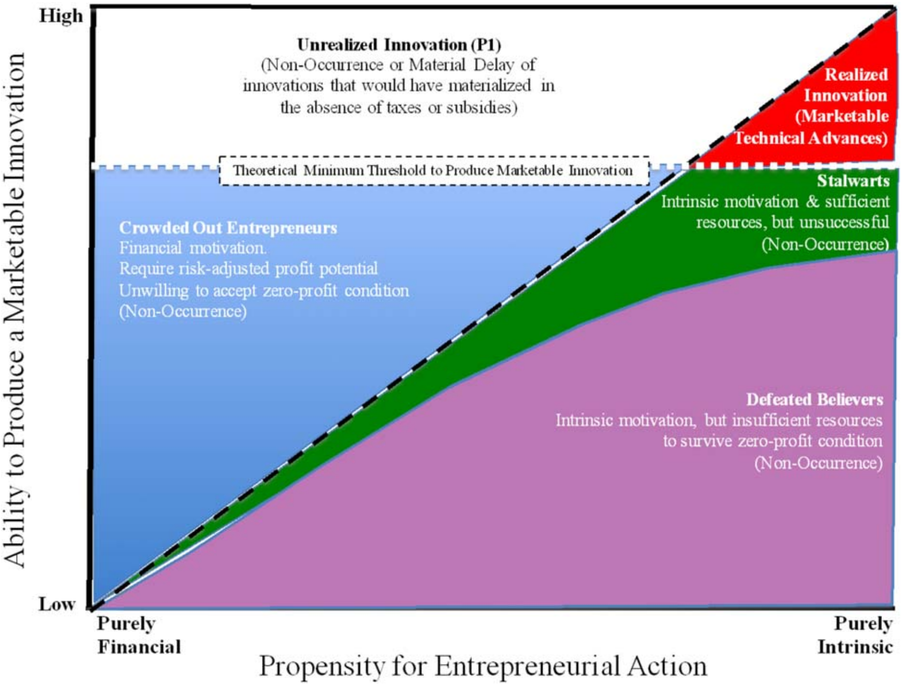

Figure 1. Crowding out effect. When subsidies or taxes create a 'zero-profit' condition, novel breakthroughs are economically indistinguishable from existing technologies, resulting in significant unrealized innovation

marketable innovation (Gnyawali and Fogel, 1994). Any entrepreneur with some propensity to act embodies an idiosyncratic mix of: (a) motivation, ranging from purely financial to purely intrinsic (Wry and York, 2015) (X-axis), and, (b) the ability or inability to develop and market an innovation (Y-axis). For individuals motivated by financial remuneration (the blue area: 'crowded out entrepreneurs'), the impetus to innovate recedes when the ability to profit from one's innovations is impeded by policies favouring existing technologies. For example, an individual who develops software that improves load balancing for solar power generation will not earn risk-adjusted profits if subsidies for solar power make inefficient load balancing economically meaningless. He or she cannot capture the value of solving the inefficiency if the costs are absorbed through subsidies or taxes that make breakthrough innovations economically indistinguishable from inefficient solutions.

Conversely, individuals who are at least partially motivated by non-financial factors may attempt to persist in their efforts to innovate even in the face of no profits. However, the presence of some intrinsic motivation is insufficient to motivate all founders to continue operating at a sustained loss. The purple area, 'defeated believers', represents entrepreneurs who have at least some intrinsic motivation but cannot self-fund indefinitely and must, therefore, suspend entrepreneurial action prior to producing a marketable innovation. The green area represents the 'stalwarts', committed entrepreneurs who possess the means to persist indefinitely despite their unsuccessful pursuit for marketable innovations. Finally, the red area consists of intrinsically motivated individuals who do not require risk-adjusted profits, who have the necessary resources to absorb financial losses, and who have the ability to produce a marketable innovation that improves upon existing technologies. All the other areas are crowded out by one or more of the following: absence of financial returns to innovation (blue), the absence of adequate resources despite intrinsic motivation (purple), or the absence of commercializable breakthroughs despite intrinsic motivation and adequate resources (green). This stylized depiction predicts that the realized innovation that ultimately does occur under policy-based conditions (red) is a fraction of the quantity, quality and diversity that would have emerged under market-based conditions (white) due to abandonment under policy-based conditions (Anderson and Huggins, 2008).

Innovative breakthroughs are not the only drivers of a sustainable existence. Institutional and socio-cultural forces, including individual behavioural modifications, also figure prominently (Meek et al., 2010; Sine and Lee, 2009; York and Lenox, 2014). Nonetheless, technological breakthroughs and novel organizational forms both constitute indispensable tools to simultaneously maintain commercial markets, create employment opportunities, and arrest the adverse effects of environmental degradation (Popp, 2010; Rennings, 2000). For this reason, policies that restrict the profitability of innovative breakthroughs are likely to impact environmental entrepreneurship (Anderson and Leal, 2001; Baumol and Oates, 1988). Since sustainable development involves a steady flow of innovations that are predicated on the ability of individuals to transform market failures into profits (Coase, 1974; Dean and McMullen, 2007), this crowding out is consequential. Fundamental changes in how entrepreneurs are able to profit from their ingenuity will in time affect the quantity and diversity of entrepreneurial activity and its outcomes (Baumol, 1993; Baumol et al., 2009). Accordingly, we propose the following:

Proposition 1: Environmental policies that subsidize environmentally desirable goods and services or tax environmentally undesirable goods and services will, in the long run, at least partially crowd out beneficial environmental entrepreneurship that otherwise would have occurred.

Path Dependence

It might be argued that crowding out effects, in and of themselves, are not necessarily a bad thing. For example, if the government can, through policy-driven fiat, accomplish desired aims better, faster or cheaper than the private sector, then it stands to reason that government should perhaps play a pronounced role in addressing market failures that lead to environmental degradation. In fact, this is a widely held belief, despite evidence of crowding out effects and other complications that may arise when market-based pricing mechanisms are abandoned (Anderson and Leal, 2001). The most significant of these additional complications pertains to path dependence, which simply means that future events are inevitably the consequence of events that have occurred in the past (David, 2007). Path dependence makes technologies susceptible to what Arthur calls 'lock-in', a set of circumstances in which commitments made to a specific incumbent technology dominates to such a degree that migration to alternative solution sets is seriously impeded (Arthur, 1989, 2007). For example, the QWERTY typewriter keyboard was developed in order to prevent key-jamming on archaic typewriters by actually slowing down the typist. And yet, even today, long after computers have eliminated the jamming problem, QWERTY persists, despite significant evidence that it is ergonomically inferior to a host of alternatives (David, 1985).

By abandoning market-pricing mechanisms, government policy interventions may unwittingly select the wrong technologies. Even when new solution sets emerge that improve upon the performance and cost of existing technologies, path dependence and the associated effects of lock-in often forestall adoption (Arthur, 2007; Rogers, 2010). Existing research has demonstrated that this is particularly true when policy-based incentive systems generate high returns for inexpensive, imitative innovations and low returns for high-risk, novel innovations (Newell et al., 1999; Popp, 2010). Subsidies and taxes that are intended to accelerate the scaling of extant technologies tend to generate immediate responses from individuals and organizations aiming to capitalize on the favourable economic treatment or cost-avoidance that accompanies scaling-friendly policies and because they leverage the roll out of extant technologies (Popp et al., 2010). For example, taxes on coal-fired plant emissions motivate firms to quickly develop and implement incremental innovations that alleviate the cost impacts of emission taxes. Meanwhile, subsidies allow entrepreneurs to take advantage of existing technologies that have been accorded preferential status in the marketplace through financial support. For instance, when subsidies were implemented for the installation of residential solar energy systems, hundreds of companies formed in a matter of weeks to provide solar panel installation services (Cusick, 2015; Victor and Yanosek, 2011). This near-term dynamic is captured in our second proposition:

Proposition 2: In the near-term, environmental policies that intentionally or unintentionally support path dependent technologies, organizational forms or business models will increase the quantity and beneficial impact of environmental entrepreneurship.

The near-term surge in environmentally beneficial outcomes contrasts markedly with longer term effects in which path dependent forces lock in engrained assumptions pertaining to extant technologies (Arthur, 2007; Newell et al., 1999; Popp, 2006) and organizational designs that leverage existing business models and value propositions (Zott et al., 2011). As noted above, lock-in operates on a self-sustaining logic that favours continuity and replication (David, 1985), even when it materially constrains the quantity and diversity of entrepreneurial activity (Anderson and Huggins, 2008). This radical turn in long-term effects is expressed in the following manner:

Proposition 3: In the long-term, environmental policies that intentionally or unintentionally support path dependent technologies, organizational forms or business models will decrease the quantity and beneficial impact of environmental entrepreneurship.

Intergenerational Fairness

The model for Propositions 2 and 3 (Figure 2) posits a theoretical threshold for sustainable existence. Although the threshold is fixed in this illustration, it would be expected

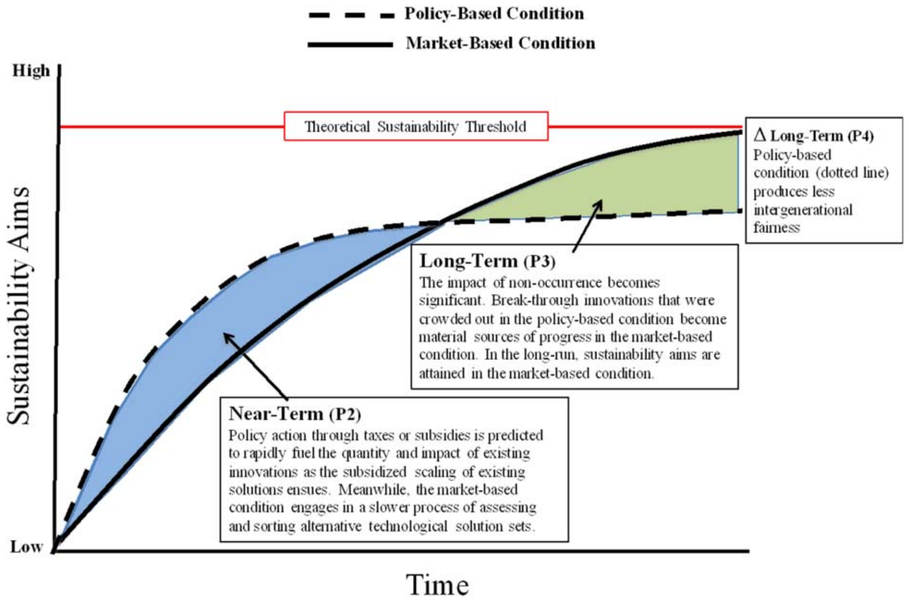

Figure 2. Path dependent effects. In the near-term, subsidies and taxes will be more effective in arresting environmental degradation than a market-based approach. Longer term, however, the policy-based approach under-performs markets due to less flexibility and fewer technological and organizational innovations

to vary markedly over time as a function of numerous foreseeable (e.g., population density) and unforeseeable (e.g., natural cataclysms) factors. For the sake of simplicity, two path-dependent conditions are considered. Both have the aim of arresting environmental degradation. The first, a policy-based condition, relies on policy actions to determine the development and diffusion of environmental technologies. The second, a market-based condition, relies on market-pricing mechanisms. Although both conditions are curvilinear, the policy-based condition is significantly steeper than the market-based condition, indicating our prediction that in the short-term sustainability aims are addressed more expeditiously when policies are used as the primary mechanism to arrest environmental degradation. However, in the long run we predict that the two conditions will intersect, indicating that over time the policy-based condition will generate less cumulative progress than the market-based condition.

The base case presented in Figure 2 predicts that a policy-based approach ultimately will be less effective in attaining sustainability. If correct, this has significant ethical implications with respect to intergenerational fairness (Barrett, 1996; Weiss, 1990). Enigmatically, concerted attempts to implement fairness-based policies may result in less intergenerational fairness. Our fourth proposition integrates sustainability, ethics and entrepreneurship on this important point:

Proposition 4: In the long-term, policies that subsidize environmentally sound goods and services or tax environmentally unsound goods and services will underperform free-market entrepreneurial activity in making progress towards intergenerational fairness.

RESEARCH DESIGN

Crowding out effects are notoriously difficult to investigate because doing so involves the quantification of non-occurrence (Gordon and Hayward, 1968). Since it is impossible to directly measure non-occurrence – innovations that are materially delayed or permanently undeveloped – one way to constructively engage the topic is through a stochastic computational model, which simulates the dynamic interplay between societal needs, institutional policies, prospective entrepreneurs and the ethical imperatives of intergenerational fairness. Methodologically, simulations have been shown to provide valuable complementary insights when purely conceptual or empirical work is insufficient (Markman et al., 2015). They are ideal when focal relationships are weakly understood, yet the underlying theory regarding a phenomenon is sufficiently developed to design a simulation model that displays internal validity and lends itself to experimental rigor (Davis et al., 2007; Zott, 2003). Prior uses of simulations have demonstrated their applicability to circumstances involving non-linearities (Carroll and Burton, 2000; Rudolph and Repenning, 2002), elusive empirical data (Davis et al., 2007), and the intricacies of environmental modelling (Popp, 2006).

Simulation Framing

By their very nature, simulation models are only approximations of reality since they are built upon an array of probabilities that must be justified with respect to the past, present and future. Our model consists of a series of probability distributions that are applied to the cross product of two matrices (Gordon and Hayward, 1968); one representing individual environmental entrepreneurs and the other representing the environmental entrepreneurship context. Through this, an indexed score was assigned to each entrepreneur (Appendix) that was then used to determine the occurrence or non-occurrence of five successive environmental entrepreneurship activities: firm formation, market entry, marketable innovation, ongoing operations and exit.

In order to identify and assess the underlying mechanisms relating entrepreneurial action to policy action, our model employed a comprehensive accounting of contextual factors that are likely to be influenced by policies. The burgeoning study of entrepreneurial environments offers an array of perspectives and frameworks (e.g., Ács, 2008; Bruton et al., 2010), assessing the impact of policy actions on entrepreneurship (e.g., Levie and Autio, 2011; McMullen, 2011; North, 2005) and the social welfare gains accrued from entrepreneurial action (e.g., Zahra and Wright, 2015). For our purposes, a useful framework needed to facilitate three research aims: (i) simultaneous consideration of policy-based and market-based conditions; (ii) conceptual integration of sustainability, entrepreneurship and ethics; and, (iii) identification and assessment of the underlying mechanisms that may be related to crowding out, path dependence, non-occurrence and material delay. Given these constraints, the frameworks derived from most prior scholarship lacked sufficient breadth in order to provide omnibus coverage of entrepreneurial environments while still being sufficiently detailed to facilitate an exploration of specific mechanisms. Of the extant frameworks that were considered, only Baumol, et al. (2009) serviced all three research aims.

At the centre of Baumol et al. are the 'entrepreneurship pillars', key facets that are required for a vibrant entrepreneurial environment: (i) ease of starting and expanding a business; (ii) rewards for productive entrepreneurship; (iii) disincentives for unproductive entrepreneurship; and, (iv) incentives to keep the winners on their toes. In adapting this framework, we made one important modification, consisting of a splitting of the two elements contained in Pillar 1. The environmental factors influencing starting and expanding a venture can be one and the same, but that is not the norm. For example, differences in bankruptcy laws impact business foundings differently from ongoing business operations (Armour and Cumming, 2008). Bifurcating the elements in Pillar 1 leaves us with five distinct categories that we operationalize in our analysis.

Simulation Structure

Given the data and design constraints associated with non-occurrence, we built the model and conducted the analysis using Monte Carlo simulation experiments with stochastic process modelling. Our model included three dimensions: environmental policy, entrepreneurial support pillars and the propensity by entrepreneurs to develop and market breakthrough innovations. In the Monte Carlo approach, each experiment is a simulation with fixed and variable parameter settings that is run multiple times (Law and Kelton, 1991). The results are then averaged and confidence intervals calculated (Kalos and Whitlock, 1986). Thus, for any given experiment, the result is the mean performance over multiple runs. Stochastic process modelling allowed us to test multiple structures (Davis et al., 2007, 2009). Each experiment consisted of 50 runs, which represented the upper limit for improvements in precision. Each period in the simulation represented 1 year. Durations ranged from 10 to 250 years. Each experiment began with 1,000 entrepreneurs, who continued or exited based on matrix cross-products described below. For each additional year of the simulation, 1,000 new entrepreneurs were added at the beginning of the year. Additional detail on the entrepreneur and context coding is provided in Appendix.

Operationalizing Baumol, Litan and Schramm's Entrepreneurship Pillars

As noted above, we did make one major modification to the Baumol et al. framework by splitting Pillar 1 – 'Ease of Starting and Expanding a Business' – into two separate categories. To distinguish Baumol et al.'s original 4 Pillars from our modified categories, we refer to our categories as 'Elements'. Sensitivity analyses comparing models based on the original four 'Pillars' with our modified five 'Elements' revealed that use of the Baumol et al.'s original formulation would dramatically reduce entrepreneurial activity in the policy-based condition. For accuracy and conservatism, we conducted our investigation using the bifurcation.

In order to operationalize each of the 5 Elements, we called upon empirical data from extant literature to develop five 'factors', each of which is an arithmetic expression of a key mechanism underlying each of the 5 Elements. As detailed in Appendix, the first four factors for each Element consists of a probability distribution related to a key driver of that factor. For the fifth factor, the state (i.e., 00, 01/10 or 11) is randomly assigned with equal probability.

Since the Pillars were not specifically focused on environmental issues, we sought to cast each of the 5 Elements in terms of how the factors would impact entrance, survival and innovation in the Cleantech sector, which consists of firms that sell products, services and processes intended to provide superior performance at lower cost, while greatly reducing or eliminating negative ecological impact and at the same time improving the productive and responsible use of natural resources (Cleantech Group, 2014). The base case probabilities for each factor reflect the extent to which the factor is a weak, moderate or strong determinant in favourably influencing entrepreneurial activity. The base case probability and associated coding is displayed in Table I.

RESULTS

The purpose of this inquiry is to address the question of how the aims of intergenerational fairness are best achieved. Although extant scholarship suggests that both public policy and entrepreneurial innovation are indispensable facets of sustainable existence, no prior research has investigated the long-term interaction between the two forces. Our inquiry drew us to two questions: First, do even well intended environmental policies, involving subsidies or taxes, crowd out entrepreneurial activity that might otherwise occur? Second, if crowding out does occur, would the path dependent nature of innovative technologies hinder or help societal efforts to achieve intergenerational fairness through sustainability? To address these questions, we advanced four propositions, tested over very long periods of time using a computer simulation.

In total, we ran more than 500 simulations, for periods ranging from 10 to 250 years. Since the focus of our research involved an attempt to quantify material delay or non-occurrence of potentially beneficial entrepreneurial activities, the analytical cornerstone of our research design consisted of head-to-head comparisons of scenarios involving market-based and policy-based conditions. Accordingly, our reporting of the results in this paper is comprised of a series of graphs that are intended to display the critical areas in which our theory successfully or unsuccessfully found support. For the sake of comprehensibility and consistent reporting, all the data was standardized and indexed, ranging from 0 to 1, so that the year-to-year fluctuations of each dimension can be studied over time in a comparable fashion.

Overall, the results show strong support for our core premises: environmental policies elicit an immediate escalation of favourable environmental outcomes, benefits that decline over time due to the combined effects of crowding out and path dependence. This suggests a sharp disjunction between short-term optima and long-term optima. Along virtually every dimension we analysed, policy-based subsidies for environmentally desirable products or taxes on environmentally undesirable products are both associated with heightened near-term entrepreneurial activity (e.g., Figures (3 and 4) and 8). Since, however, this activity arises as a consequence of massive investments in existing technologies (Figures 8 and 11), there are longer term effects that gradually erode the policy benefits, before erasing the benefits of subsidies and taxes altogether (Figures 9 and 12).

Consistent with prior literature comparing the relative impacts of subsidies and taxes (Jaffe et al., 2003) our simulation results reveal that taxes on undesirable products result in more long-term innovation than subsidies for environmentally desirable products (Figures 10). This finding led us to modify the analysis and report subsidy effects separately from tax effects. Differences between taxes and subsidies are likely related to the

Table I. Operationalization of the entrepreneurship pillars (Baumol et al., 2009)

Element 1: The Ease of Starting a Business

		Base Case Distribution		
Factor	*Sources*	*0-0*	*0-1/1-0*	*1-1*
1. Returns to Imitation	Baumol, 1993, 2006; Enkle and Gassmann, 2010; Meisenzahl and Mokyr, 2009; Schmitz, 1989	P: 15% M: 35%	P: 30% M: 50%	P: 55% M: 15%
2. Returns to Innovation	Akcigit et al., 2013; Bessen and Maskin, 2009; Green and Scotchmer, 1995; Rumelt, 1984	P: 60% M: 40%	P: 35% M: 40%	P: 5% M: 20%
3. Property Rights	Alston and Mueller, 2005; Anderson and McChesney, 2003; Grossman and Hart, 1986; Johnson et al., 2002	P: 40% M: 10%	P: 40% M: 50%	P: 20% M: 40%
4. Regulatory Climate for SMEs (e.g., bankruptcy and healthcare laws)	Anderson and Leal, 2001; Baumol et al., 2009; Kerr and Nanda, 2009; PERC, 2014; Storey, 2003;Van Stel et al., 2007	P: 20% M: 40%	P: 30% M: 40%	P: 50% M: 20%
5. Random Effects	N/A	P&M: 33.3%	P&M: 33.3%	P&M: 33.3%

Element 2: The Ease of Expanding a Business

		Base Case Distribution		
Factor	*Sources*	***0-0***	***0-1/1-0***	***1-1***
1. Market Concentration	Carroll, 1985; Cleantech, 2014; Rumelt, 1984; Shaked and Sutton, 1983	P: 40% M: 50%	P: 40% M: 40%	P: 20% M: 10%
2. Interest Rate and Financial Environment	Black and Strahan, 2002; NFIB, 2015; Shane, 1996	P: 20% M: 50%	P: 35% M: 30%	P: 45% M: 20%
3. Addressable Market for Novel Innovations	Akcigit et al., 2013; Bessen and Maskin, 2009; Green and Scotchmer, 2008	P: 60% M: 30%	P: 30% M: 40%	P: 10% M: 30%
4. Addressable Market for Incremental Innovations	Baumol, 2006; Brynjolfsson et al., 2006; Meisenzahl and Mokyr, 2010	P: 10% M: 50%	P: 30% M: 30%	P: 60% M: 20%
5. Random Effects	N/A	P&M: 33.3%	P&M: 33.3%	P&M: 33.3%

Element 3: Rewards for Productive Environmental Entrepreneurship

		Base Case Distribution		
Factor	*Sources*	***0-0***	***0-1/1-0***	***1-1***
1. Appropriability of rents for incremental innovations	Baumol, 2006; Hunt, 2013; Meisenzahl and Mokyr, 2010	P: 15% M: 60%	P: 30% M: 30%	P: 55% M: 10%

Table I. *Continued*

Element 3: Rewards for Productive Environmental Entrepreneurship

Factor	Sources	Base Case Distribution 0-0	0-1/1-0	1-1
2. Appropriability of rents for novel breakthroughs	Akcigit et al., 2013; Bessen and Maskin, 2009; Green and Scotchmer, 1995	P: 70% M: 40%	P: 25% M: 40%	P: 5% M: 20%
3. VC Cleantech Funding	NVCA, 2015	P: 30% M: 20%	P: 50% M: 50%	P: 20% M: 30%
4. IPOs for Cleantech Firms	NVCA, 2015; Cleantech, 2014	P: 60% M: 10%	P: 30% M: 40%	P: 10% M: 50%
5. Random Effects	N/A	P&M: 33.3%	P&M: 33.3%	P&M: 33.3%

Element 4: Disincentives for Unproductive Environmental Entrepreneurship

Factor	Sources	Base Case Distribution 0-0	0-1/1-0	1-1
1. Oligopolistic Market Control	Kirzner, 1978; Rumelt, 1984; Shaked and Sutton, 1983	P: 15% M: 30%	P: 40% M: 50%	P: 45% M: 20%
2. Restrictive Patenting Laws	Moser, 2003, 2013; Park, 2008; Penrose, 1973; Sakakibara and Branstetter, 2001	P: 40% M:30%	P: 35% M: 30%	P: 25% M: 40%
3. Anti-Fraud and Corruption Regime	Acemoglu and Verdier, 1998; Aidt, 2003; Anokhin and Schulze, 2009; Baumol, 1996	P: 20% M: 10%	P: 40% M: 40%	P: 40% M: 50%
4. Legal Environment	Alston and Mueller, 2005; Baumol, 1990, 1996; Compustat Data	P: 60% M: 30%	P: 30% M: 40%	P: 10% M: 30%
5. Random Effects	N/A	P&M: 33.3%	P&M: 33.3%	P&M: 33.3%

Element 5: Keeping Incumbents on Their Toes

Factor	Sources	Base case distribution 0-0	0-1/1-0	1-1
1. Cross-Border Patent Recognition	Macedo, 1990; Moser, 2003, 2013; Park, 2008; Penrose, 1973	P: 55% M: 20%	P: 35% M: 30%	P: 10% M: 50%
2. Incentives to incumbents	Kent and Meyers, 2001; Popp, 2005, 2006; Porter and Van der Linde, 1995	P: 40% M: 70%	P: 35% M: 25%	P: 25% M: 5%
		P: 60%	P: 30%	P: 10%

Table I. *Continued*

Element 5: Keeping Incumbents on Their Toes				
		Base case distribution		
Factor	*Sources*	***0-0***	***0-1/1-0***	***1-1***
3. R&D as % of GDP	NSF Data; Compustat Data; PhRMA Data	M: 10%	M: 40%	M: 50%
4. New Tech Speed to Market	Bayus, 1997; Benner and Tushman, 2003; Fang, 2008; Tripsas and Gavetti, 2000; Schoonhoven et al., 1990	P: 60% M: 10%	P: 30% M: 40%	P: 10% M: 50%
5. Random Effects	N/A	P&M: 33.3%	P&M: 33.3%	P&M: 33.3%

fact that taxes increase the cost structure of product manufacturers and service providers, creating an incentive to reduce that cost through targeted innovations. This is tantamount to leaving the entrepreneurial rents at least partially intact. The finding also provides support for work by Dean and McMullen (2007) and Popp (2010), predicting that policies specifying favoured technologies are likely to underperform policies that create new incentives, while keeping market forces intact. While taxes are preferable to subsidies, they too underperform market mechanisms long term (Figure 10).

Firm Formation and Market Entry

Our theory predicted that, in the long run, environmental policies crowd out or materially delay beneficial entrepreneurial activity that would otherwise have occurred in the absence of government-mandated subsidies or taxes. However, we noted that the opposite is likely to occur in the short-term. As indicated in Figures 3 and 4, the market-based scenario exhibits far fewer firm formations and market entries in the first decade. This is supportive of Proposition 2.

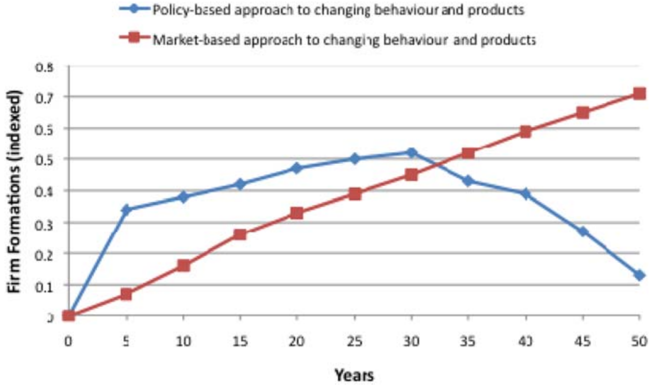

Figure 3. Firm formation comparison: Policy vs. market-based conditions

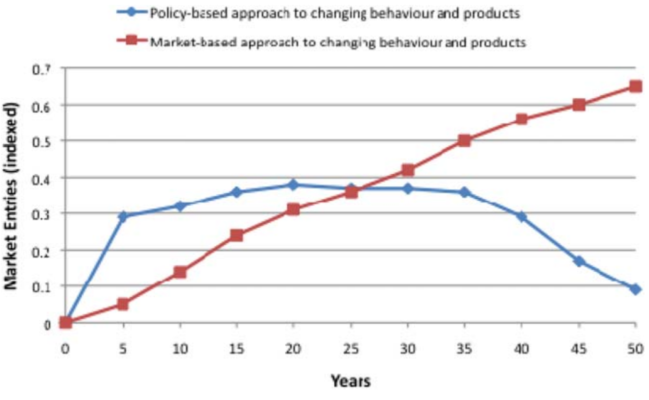

Figure 4. Market entry comparison – policy vs. market-based conditions

While year-over-year simulation results in Figures 3 and 4 display a rapid reaction to the implementation of new policies, Figure 5 demonstrates that this surge in firm formations and market entries is almost exclusively due to subsidies. It appears that taxes designed to discourage environmentally undesirable behaviours and products are far slower to elicit firm formations and market entries. Meanwhile, subsidies – especially those intended to accelerate the scaling of extant technologies – generate immediate responses from individuals and organizations intent on aiming to capitalize on the favourable economic treatment that accompanies subsidy-focused policies (Figure 6).

The reason for this is likely related to the ways in which an entrepreneur would profit from creating ways to exploit a subsidy versus avoiding a tax. Subsidies are more immediately responsive to addressable market mechanisms because they tend to leverage the roll out of extant technologies. Meanwhile, the returns to incremental innovation derived through taxes are slower to form than the rollout of existing, subsidized products. However, taxes generate a larger number of innovations since tax avoidance requires the development of new resources, processes or technical solutions. This dynamic is investigated further in Figure 10.

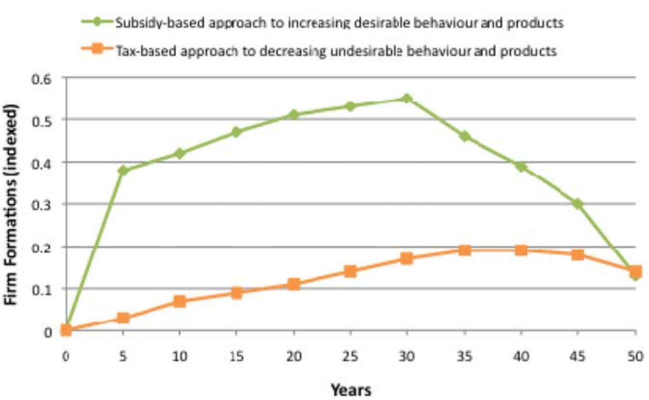

Figure 5. Firm formations: subsidies versus taxes

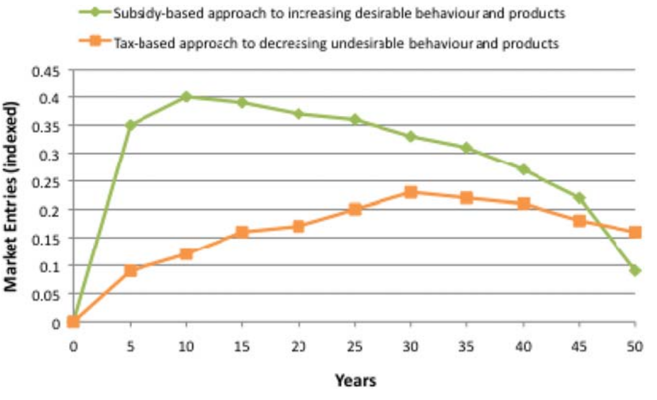

Figure 6. Market entry: Subsidies versus taxes

Although new firm formations and market entries are heightened short-term through policy action, the relative benefits of entrepreneurial action via a market-based approach to environmental degradation begin to reverse after 10 years, post-implementation. This reversal is consistent with prior research demonstrating that, at least initially, more proximal and accessible opportunities will be preferred over those deemed to be riskier and more distant (Benner and Tushman, 2003; Dosi, 1982; Jaffe et al., 2003; Popp, 2010). Longer term, however, the advantages are less clear. While the policy-based scenario eventually trends towards oligopolistic industry structures, characterized by a small cluster of cost-conscious firms (Baumol and Oates, 1988; Dosi, 1982; Popp, 2010), the market-based solution exhibits a growing population of new firms (Figures 3 and 4).

Operational Longevity

From the outset, market-based conditions result in greater longevity of entrepreneurial ventures than that observed under policy-based conditions (Figure 7).

Part of this finding is due to the stampede of short-lived, unfit firms in the policy condition, reflecting over-optimism to munificent environmental conditions (Barnett,

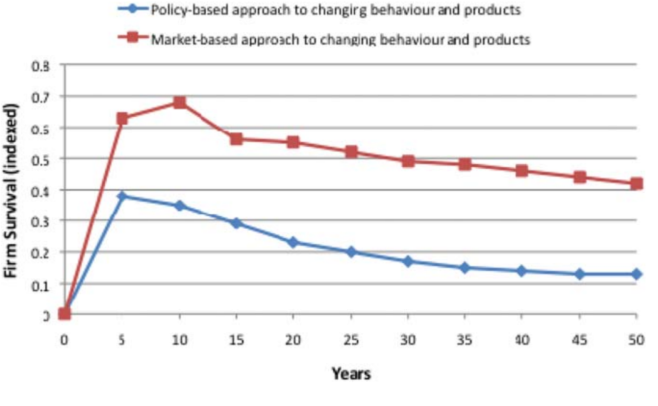

Figure 7. Comparison of firm longevity: Policy vs. market-based conditions

et al., 2003; Swaminathan, 1996), particularly those arising from more favourable institutional policies (Hunt, 2015). The lower survival rates under policy-based conditions arise due to cutthroat competition to cheaply replicate existing technologies. The key mechanism associated with the divergence in firm fate across the policy-based and market-based conditions appears to be the paucity of technical differentiation associated with the policy-based condition. This mechanism embodies the tendency of under-differentiated sectors to drift towards oligopolies, as Dosi (1982) predicted. Conversely, market-based conditions provide incentives to develop alternative paradigms, since entrepreneurial rents will accrue to the innovators of breakthrough, differentiable technologies.

Innovation

Our theory predicts that environmental policies tend to crowd out innovations that would otherwise occur under market-based conditions because a policy-based approach creates near-term incentives to implement existing technologies and this has an adverse long-term impact on the incentives to develop and market innovative breakthroughs. Since the processes of technical and organizational innovation are path dependent, policies that place non-competitive technologies and organizational forms financially on par with radical breakthroughs may foreclose upon future innovations. If true, then the simulation results should exhibit more numerous and impactful innovations emanating from market-based conditions than policy-based conditions, and the innovation gap should increase over time.

As the results in Figure 8 reveal, the central premise of our theory finds support on these points. Initially, there are more innovations under the policy-based condition, post-policy implementation. But this relationship reverses between years 15 and 20 of the simulation.

It appears that the decisive mechanisms governing firm formation and market entry shift from conditions favouring returns to imitation to conditions favouring returns to innovation. As the Baumol et al. taxonomy suggests (Table I), mechanisms that draw out rapid firm formation and market entry may differ from the mechanisms that

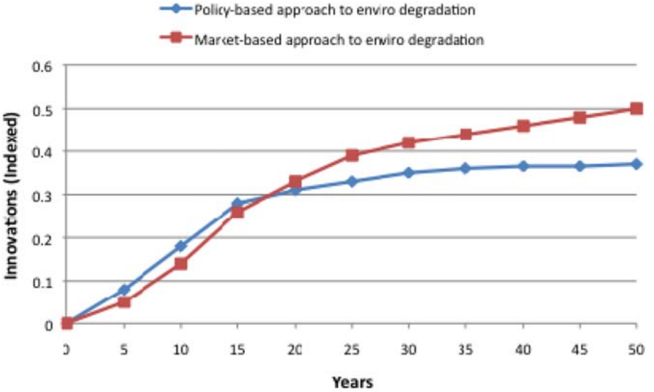

Figure 8. Innovations −50-year horizon: Policy vs. market-based conditions

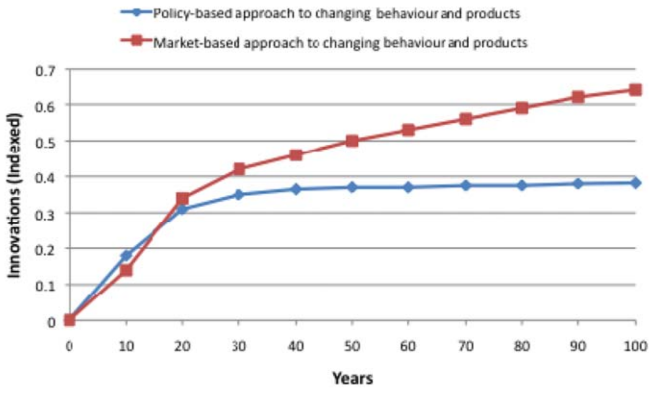

Figure 9. Innovations −100-year horizon: Policy vs. market-based conditions

generate rewards for ongoing productivity, most notably the ability of a market participant to appropriate rents from novel breakthroughs. Since subsidies favours imitation, technical differentiation fails to fully develop and returns to innovation are not rewarded in the marketplace, causing a reversal that becomes more and more pronounced over time, as indicated in Figure 9.

This initial surge is due almost entirely to the effect of policies in which taxes are instituted. As Figure 10 reveals, subsidy-focused policies have little impact on innovation, which is consistent with the earlier finding that entrepreneurs will primarily enter the market to sell existing products that receive favourable treatment under subsidy programmes. Conversely, taxes appear to foster an early wave of innovations in a cost-driven attempt to engineer around the tax assessment.

Intergenerational Fairness

As the foregoing results demonstrate, significant differences in new firm formations, market entries and innovations arise over very long periods of time. The question is: Are these differences consequential to the aims of intergenerational fairness? Since there is no fixed unit of measurement for the attainment or non-attainment of sustainable

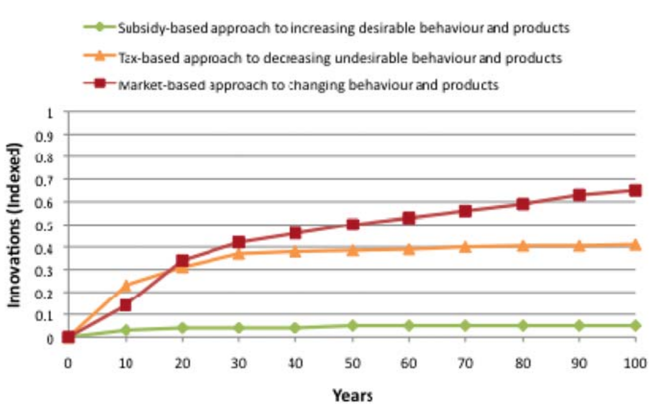

Figure 10. Innovations: Subsidies versus taxes with a 100-year horizon

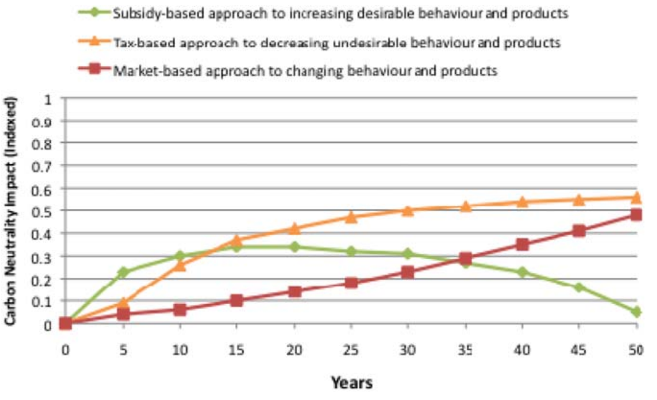

Figure 11. Comparative progressions toward carbon neutrality: 50-year horizon

development, it is impossible to conduct a long-term empirical comparison between policy-based and market-based approaches to the reversal of environmental degradation. However, it may be possible to use a proxy for progress towards intergenerational fairness, such as carbon neutrality. Environmental economists maintain that the scope of global carbon neutrality is likely to require many generations of innovation, including new technical paradigms that are yet to be conceived (Popp, 2005; Popp et al., 2010; Porter and Van der Linde, 1995). The combination of long timeframes, path dependence and the essentiality of technical innovations, makes carbon neutrality an interesting test for our simulation model. Combining carbon calculation mechanisms synthesized from seven different sources by Wiedmann and Minx (2008) - including, the Carbon Trust, ETAP, Global Footprint Network and Parliamentary Office of Science and Technology – we have recast the theoretical model presented in Figure 2 to focus on carbon neutrality.

The results of a 50-year (Figure 11) and a 250-year (Figure 12) simulation are shown below. Three scenarios are modelled: a policy-based response using subsidies, a policy-based response using taxes, and a market-based response that excludes any form of

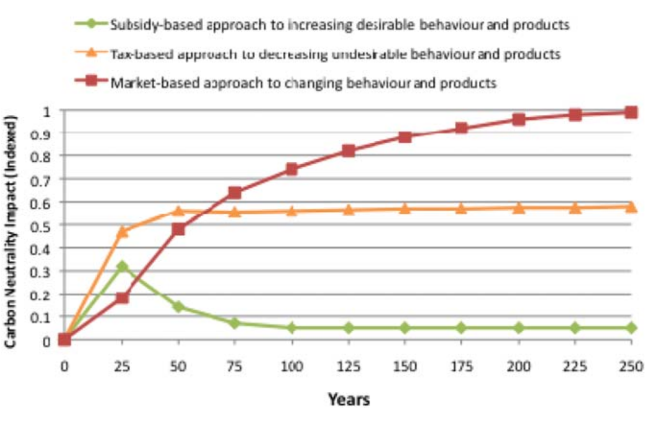

Figure 12. Comparative progressions toward carbon neutrality: 250-year horizon

government policy. Both figures display the results under the assumption that neither of the other two scenarios operates concurrently. Each of the three lines represents an exclusive condition, whereby the other two conditions are excluded for a given simulation. In reality, various combinations of the three can and do exist, and we conducted some testing of hybrid conditions to see if new minimums or maximums could be achieved that would move the outer boundaries of the simulation outcomes. None of the hybrid conditions that we tested resulted in a higher maximum or lower minimum than the thresholds captured through use of the three conditions.

The initial conclusion one would draw from Figure 11 is that subsidies reliably deliver a predictable and immediate impact. However, the immediate results do not reflect longer-term effects because eventually tax-based environmental protections provide a stronger, more sustained payback, thereby eclipsing the advantage that subsidies display in the first five years. Environmental policy decisions that focus only on the initial years post-implementation are likely to err in expecting subsidies to continue to generate improvements. In fact, our model actually shows a reduction in the effectiveness of subsidies after the 15-year mark. While limits are apparent in the tax-based condition, as well, a far more severe technological 'lock in' (Arthur, 1989) occurs with subsidies; so much so that they cannot keep pace with population growth.

Also conspicuous in the 50-year carbon neutrality comparison is the slow pace of environmental impact that occurs in the case of a market-based response to environmental degradation. The longer ramp-up stems from its reliance upon the diffusion of competing innovations. The comparative attractiveness of policy-based responses is manifested in the generation of early results – and this is exactly the challenge, as well. As Figure 12 shows, when the simulation is run for 250 years, a market-based approach eclipses tax-based policies shortly after the 50-year mark, with the difference steadily increasing until neutrality is achieved in approximately 225 years. The longer timeframes reveal an unpromising fate for policy actions.

Considered from the perspective of material delay or non-occurrence, policy-based approaches to environmental degradation reduce innovations that would have otherwise emerged in a market-based approach. The impact 50 years post-implementation is a 26 per cent reduction in innovation, and 100 years post-implementation is a 41 per cent reduction. By unwittingly crowding out environmental entrepreneurs, well-intended policies that employ subsidies forestall innovation to such an extent that 225 years post-implementation – the point at which a market-based approach would have established sustainability – subsidies lag the market-based approach by 95 per cent (Figure 12). In this sense, and in support of Proposition 4, market-based entrepreneurial innovation displays a marked advantage over policy actions in the achievement of intergenerational fairness.

Robustness: Sensitivity Analysis of the Simulation Structure, Content and Results

The core requirement of any simulation model is that it is not susceptible to small changes in the underlying assumptions. This risk necessitates rigorous sensitivity analysis.

To ensure the conservatism of the base case probability distributions we tested more than 1,200 permutations of the environmental context matrix (i.e., 10 tests each for 24 stochastic values, for each of the five model elements). The results of this analysis confirmed that any other set of probabilities would result in stronger support for the four propositions. Additionally, we conducted sensitivity analysis for each model dimension that is based on uniform distribution assumptions, for which there are three: the annual entry rate of entrepreneurs, the milestone critical thresholds (see Appendix), and the proportion of financially versus intrinsically motivated entrepreneurs (see 'Implications for Environmental Entrepreneurs' below). In each case, any deviation from the base case distributions strengthens our findings. Conservatism thus dictated reporting on results drawn from the base case distributions.

Since there are randomly assigned components to each of the bit strings that form the entrepreneur and contextual matrices in our model, there is an inherent variability to the outcomes for each experiment. Applying standard protocols for Monte Carlo analysis (Law and Kelton, 1991), we conducted multiple runs (n = 50) of each experiment and took the mean value for each series. Given that the mean values derived from any observations of simulated or empirical stochastic processes display variability in error variances, this facet was assessed with respect to the associated confidence intervals (Law and Kelton, 1991). Following the procedures of Davis et al. (2009), we subjected these error variances to robustness tests in which the square root of the variance of each experiment is compared to the array of simulation runs. The results of this analysis provided ample statistical support that the results we obtained can be summarized as follows: they are not a consequence of chance; they are statistically different from the null hypothesis; additional simulation runs would not result in statistically distinguishable outcomes; and, there is no evidence that the underlying error variances either compound or cancel out in a fashion that would invalidate our conclusions.

DISCUSSION

The complex nexus of sustainability, ethics and entrepreneurship is wracked with puzzles and contradictions. That which is beneficial short-term, may be costly long-term. Our proposed framework does not resolve all of these issues, but it does offer the analytical means to assess the tradeoffs that impact intergenerational fairness. These findings have significant implications for scholars, policymakers and entrepreneurs.

Shakespeare (1602) wrote, 'It is better to be 3 hours early than 1 minute late'. Escalating concerns about the steep costs and diminished quality of life that may befall future generations under a regime of market-based mechanisms (e.g., Klein, 2015) has led some scholars to call for immediate, enforceable international measures to curtail greenhouse gas emissions and other environmentally undesirable outputs (e.g., Van den Bergh, 2004; Weiss, 1990). Given these heightened concerns, the urgent appeal for decisive policy actions is a rational response to the possibility that time is running out for the implementation of steps that ensure intergenerational fairness. The fear is that we may be too late. However, the results of the foregoing analysis suggest that attempts to address environmental degradation primarily through policy measures amount to showing up on time, but with an ineffective set of tools for the attainment of intergenerational fairness because, in the long run, subsidies and taxes reduce intellectual diversity, limit competition and stunt the development of innovative solution sets.

We find that even well-intended efforts to forestall environmental degradation through subsidies and taxes ultimately crowd out entrepreneurial innovations that are critical to the achievement of sustainable human existence by unintentionally throttling technological progress and organizational innovations that are decisive to the achievement of sustainable existence.

Implications for Research

Our study presents challenges and opportunities for scholars ranging across diverse fields. First and foremost, the findings demonstrate that time-variant effects are indispensable determinants of whether or not sustainability is attained. The centrality of time to the relationships formed through the nexus of sustainability, ethics and entrepreneurship requires that useful frameworks must be able to define, assess and predict both intended and unintended outcomes. Taking into account the complex interactions between environmental policies and entrepreneurial environments, examined over long expanses of time, our framework offers the first unified treatment of crowding out and path dependence as they pertain to environmental entrepreneurship. By combining these related effects, our study clarifies the long-term issues that characterize the reciprocating influences between public policy initiatives and environmental entrepreneurship.

Prior studies on crowding out effects have examined a wide range of contexts, (Abrams and Schitz, 1978; Czarnitzki and Fier, 2002; Wallsten, 2001), but none to date has investigated the inter-play between environmental policy and environmental entrepreneurship, and none prior to this study has explicitly undertaken a conjoint analysis of crowding out and path dependence. The results of our simulation suggest that it is important to do so. We found that government sustainability policies are inherently non-neutral, meaning that subsidies and taxes crowd out market participants who possess the capacity to add value. In this sense, well-intended environmental policies imperfectly substitute for the activities of environmental entrepreneurs, causing new technologies and organizations to be lost or materially delayed.

In light of our findings, future studies should examine the conditions under which entrepreneurs are more or less dramatically impacted by specific policy measures. Leveraging the framework we have developed, it would be productive to ask: Is it possible for public policies to serve as a sort of 'placeholder' while technological and organizational innovations are developed? If not, how might societies recover from the adverse effects of technological and organizational lock-in? Are there ways to minimize path dependent impacts by simultaneously supporting scaling efforts and nourishing a diversity of emergent solution sets? If so, what are the micro-mechanisms that would enable the coexistence of policy aims and entrepreneurial action? Are there public-private hybrid solutions that leave value-enhancing environmental entrepreneurship intact?

A number of boundary conditions apply to the scope of our inquiry, each of which offers compelling opportunities for future research. First, our focus is on new and small market entrants since our goal is to examine the complete lifecycle of entrepreneurial action, from ideation to exit. However, corporate entrepreneurship is instrumental to sustainability and it would be useful to explore the extent to which findings from that context parallel those from our study. Second, our design focuses on policy-dominant and market-dominant conditions, for which we assume that there are significant costs associated with attempts to migrate across technology paradigms. This approach may not fully account for the potential spillover effects in hybrid conditions. Future research may wish to examine whether crowding out and path dependence are neutralized by spillover benefits that might materialize in hybrid conditions. Third, our model is constructed to identify the non-occurrence and material delay of entrepreneurial innovations; however, we are not able to quantitatively assess a 'better late than never' condition. While material delay is intuitively preferable to non-occurrence, we are unable to measure the exact difference computationally. Finally, our study is bounded by the 'zero-profit' assumption of policy interventions that arise when policies situate average, existing technologies on equal economic footing with novel breakthroughs (Figure 1). Our approach does not invalidate the possible presence of partial conditions, involving both policies and market forces; indeed, that is usually the case in reality. However, the quantification of partial non-occurrence remains a future research opportunity, to which our study's findings can be compared and contrasted.

Implications for Policymakers

From a policymaker's perspective, our investigation poses challenges and opportunities. Given the highly charged nature of sustainability concerns, a 'wait and see' approach is unlikely to be a viable option. To this, we offer two observations. First, policies that have a low impact on the entrepreneurial environment are preferable to those with a high impact. Not all five Elements exert equal influence on the quantity and quality of entrepreneurial activity. Table II provides a capsule of the variance attributable to each Element. As Table II reveals, 40 per cent of the performance variance between markets and policies is attributable to Element 3, 'rewards for productive entrepreneurship'. This means that reductions in an entrepreneur's ability to profit from innovation is the primary driver of crowding out effects. Policymakers can best minimize the adverse impact of policy on innovation by avoiding measures that significantly reduce the returns to innovation.

A second facet for policymakers to consider is that direct support for diversified innovation is better long-term than support for the scaling of existing technologies. As Spulber noted (2014), under conditions of dynamic technological change, it is unlikely that a single, specified invention is capable of servicing the evolving requirements of an entire market on an ongoing basis. Given this, policy incentives to discover new technologies, such as R&D subsidies, may be a better way to broaden the array of competing solution sets in response to environmental degradation. However, subsidies that are designed to expedite mass scaling of incumbent technologies, dissociate inventions from the seller's true costs and the buyer's true willingness to pay. This, in turn, influences the economic decisions of innovators, producers, investors, and consumers (Hayek, 1945; Spulber, 2014) by rewarding scale over innovation. Given this, intergenerational fairness may best be served when policies spur innovation, rather than subsidize of scaling efforts.

Table II. Relative predictive role of entrepreneurship pillars (from Baumol et al., 2009)

Element	*Observed impact in the simulated model*	*Attributable long-term variance between market and policy-based conditions*
1. Ease of starting a business	Subsidies initially offered socio-political and cognitive legitimacy to new ventures (Aldrich and Fiol, 1994), but this created a contagion-like effect that invited entry. Simulated firm formations and market entries steadily grew in the market-based condition, but repeatedly ebbed and flowed in the policy-based condition.	17%
2. Ease of expanding a business	Lifespans in the policy-based conditions of the simulation were far shorter, reflecting the difficulties seen in contagion-style entry of unfit firms (Hunt, 2015). The advantageous status becomes a liability.	7%
3. Rewards for productive entrepreneurship	Policy-based approaches in the simulation eroded the value of breakthrough technologies and impinged upon entrepreneurial rents.	40%
4. Disincentives for unproductive entrepreneurship	Policy-based approaches, especially those using subsidies, created incentives rather than disincentives for short-term actions, and were characterized by protections for below-average solutions.	12%
5. Incentives to keep the winners on their toes	Subsidy and tax-based approaches reduced the array of scalable competing technologies, causing a more rapid move towards oligopolistic conditions.	24%

Implications for Environmental Entrepreneurs

Individuals self-selecting to the challenges of developing private-sector solutions to environmental degradation do so for some combination of financial and non-financial reasons (Wry and York, 2015). Regardless of an entrepreneur's personal motives, the same questions are relevant: What is the fate of each entrepreneur's organization? What becomes of their innovations? Is sustainability best left to social entrepreneurs who are driven by intrinsic aims?

One of the key assumptions of our baseline model is that the role of financial and non-financial motivators in eliciting and sustaining environmental entrepreneurship is evenly distributed across the spectrum from purely financial to purely intrinsic (Figure 1). That is, there is an equal chance that an environmental entrepreneur will be motivated by financial considerations or intrinsic factors, such as social concerns, ethical imperatives, intellectual enjoyment or simple curiosity. It is reasonable to question whether the uniform distribution assumption is an accurate representation of reality. In all likelihood it is not. Numerous scholars and social commentators have noted the importance of personal, moral, ethical and socio-cultural drivers of social, cultural, institutional and environmental entrepreneurship (e.g., Conger, York and Wry, 2012; Gao and Bansal, 2013; Wry and York, 2015). Therefore, in order to ensure that our findings are robust to these concerns, we conducted experiments with scenarios that tilted the motivational spectrum heavily towards intrinsic forces, meaning that environmental entrepreneurs would be far less likely to abandon entrepreneurial activity due to financial considerations.

Unlike the baseline model, which assumes uniform, 50:50 distribution, a 75:25 tilt towards intrinsic motivators, means that only 250 of the 1,000 new market entrants each year would make decisions with any consideration to profits. Overall, we ran the model 50 times, for periods of up to 250 years, using an intrinsic bias of various thresholds, ranging between 60 per cent and 100 per cent. Increasing the weighted percentage of intrinsic motivation did in fact increase firm formations, market entry decisions and the total innovations produced. However, the increase in innovations among intrinsically motivated entrepreneurs was greater in the market-based condition than it was in the policy-based condition. For example, the 75 per cent threshold drove a 30 per cent increase in innovations in the market-based condition and only a 4 per cent increase in innovation in the policy-based condition.

This means that even entrepreneurs who are intrinsically motivated are substantially better off without taxes and subsidies. Consistent with the perspectives of Spulber (2014) discussed above, government-sponsored support for an existing technology leads to lock-in, which creates steep switching costs for breakthrough alternatives, regardless of whether the innovation is generated by a financially motivated or intrinsically motivated entrepreneur.

Policies, Innovation and the Search for Intergenerational Fairness

The ethical imperatives of intergenerational fairness are not confined to environmental issues. Other issues – sovereign debt, the acts and outcomes of warfare, access to and quality of educational opportunities, and the adequacy of ongoing infrastructural investments – are also germane to attaining and maintaining a quality existence. It is, however, in the consumption of finite resources that the commitment of contemporary peoples to the fate of future peoples is most rigorously put to the test (Gore, 2006). Gao and Bansal (2013) asserted that key to sustainability is the migration by firms from the use of instrumental logics, which involve sequential decision-making that aim to minimize the impact of sustainability costs, to integrative logics, which embraces the mutual aims of economic, social and environmental well-being. Through an integrated perspective, Gao and Bansal envisioned the enactment of sustainability programmes. This is an interesting notion that should be tested in the context of entrepreneurship.

If this *Special Issue* only sought to examine sustainability and business ethics, then it is likely that the Gao-Bansal formulation would suffice. That is, large, globally operating firms can and should be held accountable for environmental degradation and the instrumental logic that perpetuates it. However, with the inclusion of entrepreneurship, the adequacy of an instrumental versus integrative rubric is called into question. While subsidies and taxes aim to achieve intergenerational fairness by supporting extant technological and organizational paradigms, environmental entrepreneurs aim to achieve the same ends through a comparatively chaotic amalgamation of competing solution sets. It is far easier to see the ethical intentions embedded in policy actions than in firms seeking to monetize technological and organizational breakthroughs, but even entrepreneurs who employ instrumental logics may produce intergenerational fairness gains. As Stepp and Atkinson noted, 'If the goal is to create a global energy system that is largely carbon free, dependence on subsidies... is not the way. Driving innovation is' (2012, p. 3).

Conclusion

Our study responds to multiple calls for careful scrutiny of the differences between policy-based and market-based approaches to one of the most vexing ethical dilemmas of our day: intergenerational fairness (e.g., Lenox and York, 2011). Existing literature seeking to integrate sustainability, ethics and entrepreneurship have amply demonstrated the essentiality of considering all three elements, but important gaps remain in addressing how environmental entrepreneurship can be left to do what it does best: to advance the aims of intergenerational fairness by producing a multiplicity of competing solution sets based on innovative technological and organizational breakthroughs. Nowhere is this more apparent than in the effort to understand how well intended public policies interact with entrepreneurial action.

ACKNOWLEDGEMENTS

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APPENDIX: SIMULATION CODING AND DESIGN

Entrepreneur Coding

Each of the 1,000 initial entrepreneurs and each subsequent entrant was assigned a 100-digit series of 0's and 1's representing the entrepreneur's relative level of financial or intrinsic motivation to engage in environmental entrepreneurship activities. At the extremes, an entrepreneur who is solely motivated by financial considerations would be coded with 100 0's, while an entrepreneur who is solely motivated by intrinsic considerations would be coded with 100 1's. For the baseline model, the 1,000 initial entrepreneurs are evenly distributed across the propensity spectrum from 1 to 100, so that each integer-level has ten entrepreneurs. The annual addition of 1,000 new entrants is structured to reflect the same distribution as the initial population. Below is a sample code for one of the ten entrants who is characterized by a 75 per cent – 25 per cent split between financial and intrinsic motivators, indicated by the 25 1's and 75 0's.

Sample Array for Entrepreneur Coding:

1111111111111111111111111111000000000000000000000000000. . ..00000000000000000
In order to build a matrix that will be multiplicative with the 5 x 5 contextual matrix (see below), it is necessary to replicate the unique 100-digit sequence for five rows, in exactly this fashion for each simulated entrepreneur, thereby creating a 5 x 100 matrix.

Contextual Coding

For each year of each experiment, a matrix was constructed representing the market-based and policy-based drivers of entrepreneurial activity expressed as a series of 0's and 1's. These drivers were structured within the framework drawn from Baumol et al. (2009). For each of the five elements, we assigned ten-digit codes, comprised of five separate pairs of 0's and 1's. Four components consist of a policy-based or market-based determinant that is coded one of three ways: 0-0, 0-1/1-0, or 1-1, reflecting the extent to which the determinant is a weak, moderate or strong factor in favourably influencing entrepreneurial activity. The final pair of each code is randomly assigned to account for unforeseeable favourable and unfavourable developments. For example, Element 3 – Rewards for Productive Entrepreneurship – might be coded as:

Sample factoring array for contextual coding – element 3:

Factor 1	*Factor 2*	*Factor 3*	*Factor 4*	*Factor 5*
00	11	01	01	??

This sequence results in a complete code for Element 3 of: '00110101??' The final two slots are each randomly assigned a 0 or 1. Elements 1 – 5 are assigned values in accordance with probability distributions that are idiosyncratic to each specific cell, and the final two digits left for random assignment. The five ten-digit sequences are stacked in a 5 x 10 matrix to form a 50-digit code that is unique to each year of each experiment.

Sample factoring array for contextual coding – complete matrix

	Factor 1	*Factor 2*	*Factor 3*	*Factor 4*	*Factor 5*
Element 1	00	11	01	01	11
Element 2	11	01	01	11	01
Element 3	01	01	00	01	00
Element 4	01	11	11	00	01
Element 5	00	00	01	11	01

The assignment of 00, 01/10 or 11 for each cell of Factors 1 – 4 was randomly determined for each simulation run by applying cell-specific probability distributions (detailed below). Using Monte Carlo simulation tools, one of the three states was selected for each run based on the unique distribution developed for that cell, based on the specific ecosystem element that was being represented in that cell. For example, Factor 1 for Elements 3 (Rewards for Productive Entrepreneurship) was *Appropriability of Rents from Technical Innovation*. The base case probability distribution for this factor, based on a review of empirical data that was drawn from innovation economics was: 77 per cent for 00, 19 per cent for 01, and 4 per cent for 11. The exception to this contextual coding process is Factor 5, for which each cell is randomly assigned one of the three states in equal proportion, thereby providing a component for unobserved random effects

Entrepreneur Index, Entrepreneurial Activity and Critical Thresholds

Once the cell codes were randomly assigned in accordance with the cell-specific probability distributions and a complete contextual matrix was assembled, the 5 x 5 contextual matrix was then multiplied by each of the 5 x 100 entrepreneur matrices one-by-one for each simulation run in each year of a given experiment. The cross products of the matrices were then averaged to produce an Entrepreneur Index, ranging from 0 to 1. In the base case, entrepreneurs with an Index score of 0.1 or less did not continue to the subsequent period, thereby creating attrition. For those that did continue, an Index score of 0.9 or above allowed the entrepreneur to advance from firm formation to market entry and eventually to marketable innovation. Once entrepreneurs enter, they remain in the simulation until the Index falls to 0.1 or less.

Experiments were staged for durations extending from 10 to 250 years. Each year was subjected to 50 simulation runs, producing a mean index for each entrepreneur that would determine whether the entrepreneur would remain in the simulated market for the subsequent year or would be dropped. Extensive sensitivity analyses were conducted to validate the 0.1 and 0.9 Index score thresholds. These analyses substantiated the conservatism of these thresholds. Any combination of higher expulsion thresholds (i.e., greater than 0.1) or lower advancement thresholds (i.e., less than 0.9) only strengthened the support for our theorized effects, meaning that less stringent thresholds resulted in statistically significant increases in the observed effects, so that our predictions actually found greater support when we migrated from these comparatively conservative thresholds. On this basis, we opted to maintain the most conservative rendering of these critical thresholds.

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