

Using Game Theory to Develop Sustainability Strategies in an Era of Resource Depletion

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Abstract

Objective: Sustainability is recognized as an important objective in business planning and is of equal relevance to policy makers. It is equally accepted, almost universally, that the resources of the planet are finite and are being over consumed on an annual basis. The prognosis therefore is that resources are being depleted and competition for access to remaining resources must ensue, as countries seek to grow and develop. This will have the effect of increasing the transaction costs of business activity as they find greater difficulty in seeking restricted supply of resources. This poses a problem for future economic activity and therefore for the achievement of sustainability. This is compounded by the fact that individual sustainability for countries or companies does not equate to global sustainability.

Method: At the same time Game Theory is recognized as a key strategic tool by policy makers and by business decision makers and is used extensively for scenario planning and strategic decision making. Although it has been recognized that Game Theory has relevance to addressing the problems of manufacturing due to resource depletion, it is surprising that no work has been done in this area. This paper therefore explains the role which this theory can play in developing strategy, and thereby promoting sustainability.

Results: It does so by developing a model which can be used in demonstrating the efficacy of planning scenarios developed in this way. For this the Prisoners Dilemma version of Game Theory is used and extended. The resulting model is then discussed and the results evaluated. Further however it recognizes the resultant problems which further need to be solved.

Conclusion: It concludes by discussing the resulting problems to propose a solution and way forward but also argues that further work is needed in order to promote sustainability and make it realistic in a global context.

Keywords: Game theory; Sustainability; Resource depletion; Transaction costs; Manufacturing competition; Earth overshoot; Consumption; Prisoners dilemma

Introduction

In 2017 Earth Overshoot Day occurred on 2 August, 6 days earlier than in 2016 and 11 days earlier than in 2015. Earth Overshoot Day is measured by the Global Footprint Network¹ and is the day when humanity has exhausted the total natural resources of the planet for the year. For the rest of the year, society operates in an effectively overdrawn mode and in ecological overshoot by drawing down local resource stocks and accumulating carbon dioxide in the atmosphere. This overshoot first occurred in 1987 and the day in which it occurs has become earlier with each succeeding year. The concept is based on the work [1].

Equally there can be no argument that the resources of the planet are finite and this is a limiting factor to growth and development. The resources available to people are heavily used - and many would say overused. So Earth Overshoot Day gets earlier each year and clearly this is not sustainable. Equally obviously once resources are used they are not available for future use and, despite the wishful thinking of economists, one resource can never completely substitute for another². The lack of sufficient resources of raw materials to maintain current production, let alone to provide for sustainable development as outlined by Brundtland has become known as resource depletion and is one of the problems which the inhabitants of the planet must currently face and address [2,3].

The depletion of the resources of the planet however is one of the factors which have helped create the current interest in sustainability³ [4]. Of particular concern is the extractive industries and such things as aluminum and tin are becoming in short supply.

¹ www.footprintnetwork.org.

² Consider for example Easter Island. Once the trees had been fully used then no resource was available as a substitute (Pakandam 2009) and such activities as sailing had to be terminated alongside the termination of the construction of the famous statues.

³ Plus all the other papers in the special issue of the Journal of Cleaner Production which was edited on the topic of Growth, Recession or Degrowth for Sustainability and Equity.

So too are many of the minerals required for the electronics industry. For example, in Malaysia the tin upon which Kuala Lumpur was founded has been fully extracted and recycling has become an important aspect of the industry. Kuala Lumpur [5] was founded for this tin because the tin^{4,5} in the UK had been fully extracted long ago [6] and the thriving industries based around them are long gone. Thus the British in their drive for development moved to exploiting the resources of other parts of the world. As other resources-such as coal-are extracted in total then the companies based upon them disappear, as do the jobs in those industries. This is an obvious source of concern for people.

On the other hand lead in the UK had been mined for over 3000 years but by the start of the 20th century was completely exhausted [7,8]. Now however the spoil from lead mining is being reworked in order to extract minerals such as fluorspar which is currently in great demand as a flux and in making enamels [9]. So it can be seen that recycling for other minerals is a feature of some mining, as is the exporting of mining technologies throughout the world. Managing in a world of depleted resources is the topic of this paper and an argument is made for a fresh approach.

Materials and Methods

Resource depletion

As stated, there is a general recognition that resource depletion is taking place [10]. This effectively means that resources are not just fully utilized but also overused so that they become in short supply [11]. A lack of resources naturally increases the transaction cost of their acquisition. It does so both because they become more scarce and difficult to acquire from more remote sources but also because competition for these limited quantities increases between the various firms which need to acquire them. It also raises the issue of recycling of already used resources and certainly this is happening as far as some minerals are concerned [12]. This is a developing aspect of business [13] and in part compensates for resource depletion but only in part. There are still finite resources which are available to be used (and re-used) and development cannot be sustainable if resources do not exist. The other factor which might mitigate this is concerned with the possibilities for substitution of one raw material or factor of production for another. In effect however substitution merely changes the competing for resources and increases their transaction costs as an increase in one industry or economy must be at the expense of a reduction elsewhere.

Depletion and renewable resources

Of particular concern is the diminishing of supplies of oil, because much economic activity is fuelled by the energy created by the use of oil. Indeed many would argue that the wars in the Middle East⁶, particularly the problems in Iraq and Iran, are caused by oil shortages, actual or impending, and the problems thereby caused, rather than by any concern for political issues. Most people have now heard of Hubbert's Peak⁷ [14] and engaged with the debate as to whether or not it has been reached. Certainly it has in parts of the world such as the USA⁸ and the North Sea but it is less certain if it has been reached for the world as a whole. Nevertheless the whole crux of sustainability and sustainable development is based upon the need for energy and there are insufficient alternative sources of energy to compensate for the elimination of oil as a source of fuel. Consequently resource depletion, real or imagined, and particularly energy resources, is one of the most significant causes of the current interest in sustainability [11].

One focus of attention as far as energy is concerned is the development of renewable energy sources as a substitute. Currently about 16% of global energy is supplied by renewable sources but 10% is from traditional biomass sources and 4% is from hydro-power. A fairly small proportion therefore is from the newer developing renewable sources and their growth is relatively rapid but fairly insignificant in the context of global energy demands. Currently global demands for energy are growing at 2% per annum but this comprises an increased demand of 4% in developing countries which is being masked by a reducing demand in developed countries caused by energy efficiency programmes⁹

Despite all the action being taken the effects are relatively small and access to energy remains one of the key factors for economic activity. Equally oil remains essential for that energy production and a key resource to consider in any analysis of sustainability. Significantly as resources become depleted the transaction costs of acquiring them increase; moreover firms need to compete with each other to a greater extent in order to acquire access to those resources.

The geopolitics of resource depletion

While people in the developed western world have been concerned with these issues, a number of countries have adopted a strategy of rapid growth and economic development [15] principal among these have been the BRIC¹⁰ countries. These countries are all geographically large and have large populations who are keen to have access to the consumerist benefits enjoyed by the developed countries. Moreover they have access to a large proportion of the remaining natural resources of the world while also having large populations and

⁴ Plus all the other papers in the special issue of the Journal of Cleaner Production which was edited on the topic of Growth, Recession or Degrowth for Sustainability and Equity.

⁵ Plus all the other papers in the special issue of the Journal of Cleaner Production which was edited on the topic of Growth, Recession or Degrowth for Sustainability and Equity.

⁶ And most probably any other parts of the world also – it would be interesting to correlate the presence of oil with conflicts.

⁷ In 1956 Dr King Hubert, a geologist working for Shell Oil developed his theory about the depletion of finite resources like fossil fuels. Now commonly known as Hubert's peak, his theory explains that production rates of oil and gas will increase to a peak and then rapidly taper off as reserves are depleted. He developed his theory to explain the coming reduction in production of oil in the USA and it is generally accepted that his theory was correct about this.

⁸ Although technology to extract oil from shale has extended this for a short period of time.

⁹ This is based upon data supplied by the International Energy Agency (IEA), the U.S. Energy Information Administration (EIA), and the European Environment Agency, who all publish similar data in this respect.

¹⁰ Brazil, Russia, India, China.

therefore great scope for rapid economic growth. This development therefore puts a lot of pressure upon the world economic system and has the effect of bidding up the cost of resources and placing a limitation upon the possibility of development by increasing the cost of economic activity and diverting resources into the bidding process instead of into production. This has the effect of reducing the pace of development and placing tension into the world economic system.

It might be argued that the rapid development of these BRIC countries has slowed in recent years indeed it might be argued that they have slipped into recession with either zero or negative growth [16]. This does not however really change the argument. Not only do these four countries contain a significant proportion of the world's reserves of raw materials, but they are also rapidly developing countries with that development fuelled by their raw materials. One consequence of this is that the resources available to other countries in the developed world are constrained by this rising demand, with a number of possible consequences. Thus access to resources becomes more important as does the geopolitics of such access.

Manufacturing and the external environment

Over the last several decades it has increasingly been overtly recognized that the activities of an organization impact upon the external environment and it is therefore suggested that such an organization should be accountable to a wider audience than simply its shareholders. Such a suggestion probably first arose in the 1970s¹¹ and a concern with a wider view of company performance is taken by some writers who show a concern for the social performance of a business, regarding it as a member of society at large. This concern was stated by Ackerman [17] who argued that big business was recognizing the need to adapt to a new social climate of community accountability, but that the orientation of business to financial results was inhibiting social responsiveness. Equally McDonald and Puxty [18] maintain that companies are no longer the instruments of shareholders alone but exist within society and so therefore have responsibilities to all of that society and that there is therefore a shift towards the greater accountability of companies to all participants. Implicit in this concern with the effects of the actions of an organization on its external environment is the recognition that it is not just the owners of the organization who have a concern with the activities of that organization. Additionally there are a wide variety of other stakeholders who justifiably have a concern with those activities, and are affected by those activities. Those other stakeholders have not just an interest in the activities of the firm but also a degree of influence over the shaping of those activities. This influence is so significant that it can be argued that the power and influence of these stakeholders is such that it amounts to quasi-ownership of the organization as a form of social contract [19].

Central to this social contract is a concern for the future which has become manifest through use of the term sustainability [20]. This term of sustainability has become ubiquitous both within the discourse of globalization and within the discourse of corporate performance.

Sustainability is of course a controversial issue and there are many definitions of what is meant by the term. At the broadest definitions sustainability is concerned with the effect which action taken in the present has upon the options available in the future [21]. If resources are utilized in the present then they are no longer available for use in the future, and this is of particular concern if the resources are finite in quantity. Thus raw materials of an extractive nature, such as coal, iron or oil, are finite in quantity and once used are not available for future use. In other words those resources become depleted a central concern for this thesis. At some point in the future therefore alternatives will be needed to fulfill the functions currently provided by these resources. This may be at some point in the relatively distant future but of more immediate concern is the fact that as resources become depleted then the cost of acquiring the remaining resources tends to increase, and hence the operational costs of organizations tend to increase¹². Thus, regardless of replaceability, the cost structure of business inevitably changes¹³ and this has implications for sustainability. Indeed an element of competition is injected and this raises the transaction costs of acquiring resources as firms must compete to acquire the restricted supply.

Sustainability implies that society must use no more of a resource than can be regenerated [22]. This can be defined in terms of the carrying capacity of the ecosystem and input output models of resource consumption can be used to describe this [23]. If an organization is considered to be part of a wider social and economic system then this implies that these effects must be taken into account, not just for the measurement of costs and value created in the present but also for the future of the business itself. This approach to sustainability is based upon the Gaia hypothesis [24] a model in which the whole of the ecosphere and all living matter therein, is co-dependent upon its various facets and formed a complete system. According to this hypothesis, this complete system, and all components of the system, is interdependent and equally necessary for maintaining the Earth as a planet capable of sustaining life.

Such concerns are pertinent at a macro level of society as a whole, or at the level of the nation state but are equally relevant at the micro level of the corporation or individual. At this level, measures of sustainability would consider the rate at which resources are consumed by the organization in relation to the rate at which resources can be regenerated. Unsustainable operations can be accommodated for either by developing sustainable operations or by planning for a future lacking in resources currently required. In practice organizations mostly tend to aim towards less unsustainability by increasing efficiency in the way in which resources are utilized. An example would be an energy efficiency programmer.

Sustainability is a controversial topic because it means different things to different people. Nevertheless there is a growing awareness that there is a debate about what sustainability means and the extent, or even if at all, it can be delivered by corporations in the easy manner they promise and as assumed by the Brundtland Commission (United Nations Commission on Environment and Development) [25]. It has

¹¹ Although philosophers such as Robert Owen (1816) were expounding those views more than a century earlier.

¹² Similarly once an animal or plant species becomes extinct then the benefits of that species to the environment can no longer be accrued. In view of the fact that many pharmaceuticals are currently being developed from plant species still being discovered this may be significant for the future.

¹³ At the present time this has become very manifest in the dramatic changes in the price of oil, firstly as a dramatic rise in price and subsequently by an equally dramatic fall in price as fracking becomes common place and Iran rejoins the world economy, and the consequences for the world economy.

become part of a policy landscape being explicitly contested by the United Nations, Nation States and big business through the vehicles of the WBCSD and ICC [26-28].

Game theory and resource consumption

All significant business decisions are strategic decisions and are games within the scope of Game theory. In other words they are games of strategy [29] which can be formulated as problems to be solved. von Neumann and Morgenstern [30] define them as problems of economics and argued that economics was too simple to provide solutions to such problems, which is why they developed their mathematical approach. It must be remembered however that in 1944 economists did not make use of mathematical modeling and barely made use of calculus even. Nevertheless von Neumann and Morgenstern [30] made use of one aspect of economics that of the assumption of rational decision making.

Various techniques have been developed by von Neumann and Morgenstern in order to solve the games and they have been used extensively not only in business decision making but also in international politics and diplomacy and in many other areas [31,32]. The skill however in solving games of strategy is not to be able to solve the games - solutions are often obvious once the problem is formulated; rather the skill lies in being able to formulate the problem and depict it mathematically in Game theory terminology. Thus problem identification is more important than problem solution - something which is often overlooked but is significant for this paper.

Although various business decision making tools of a mathematical nature, such as risk analysis, can be useful tools then when it comes to making strategic decisions it is generally accepted that the most useful tool is Game theory. This is particularly helpful when deciding about the consumption of raw materials because just as in making many engineering and management decisions it is important to recognize that the decision is not made in isolation and that the effects of the decision cannot be realistically quantified as if that decision is made in isolation. This is particularly true when the external environment is affected by the decision. In such circumstances it is not sufficient to consider how the decision might affect the firm itself or how it might be received by its customers. It is also necessary to recognize that the firm's competitors will be affected by the decision and may very well decide to respond to the actions of the firm. In such a situation the firm and its decision makers can be regarded as either in competition with another firm and its decision makers or in conflict and the generic term to describe this kind of situation is that of a game and Game theory can help to model this kind of situation and therefore improve the decisions which are made [33].

Essentially Game theory formulates strategic decisions so that they are subject to mathematical analysis and this requires the transposing of events and outcomes into a numerical format. In business this is frequently assumed to be financial numbers but in game theory this is not necessary. Instead outcomes can be quantified in terms of utility. Utility is a concept which was first formulated by the economist Marshall [34] to represent a measure of personal preference which might not be in financial terms but rather in use value received. It is a representation of satisfaction and is based upon the concepts of Classical Liberal Economic Theory as epitomized by the philosophical approach to satisfying individuals known as Utilitarianism developed

by Mill [35]. It is however a concept which is not without problems in considering regulation of markets [36].

Utility was adopted by Game theorists as a way of measuring outcomes and was adapted by von Neumann and Morgenstern to be represented by probabilities when precise outcomes were not known (or were multiple) [30]. Copeland [37] describes this as replacing the marginal utility theory with something more useable while Simon [38] describes this as a significant advance. It means in effect that all strategic problems can be mathematically quantified without precise knowledge of outcomes as it is only relative preferences which are significant to most such decisions. In theory the concept of utility enables all outcomes to be quantified for comparative purposes but this is overly simplistic. For example Markowitz [39] showed that relative size of absolute values affected choices made while Scodel et al. [40] showed that choice is made according to the subjects values thus demonstrating that utility is relative rather than absolute. Equally Luce and Raiffa [41] showed that gambling took place depending upon perceived odds. Thus the concept of utility enables quantification of problems but it is a mistake to assume that every person's choice of a rational outcome is identical.

The logic of the argument in this paper is that there are only two possible strategies - competition and collaboration and in a simple game the best result is always obtained by competition. But when there is a continuous series of games the best result is always obtained by adopting the strategy used last by the other side [42]; effectively the only viable decisions therefore are for both parties to adopt the same strategy. This only works for a zero sum game: in the scenario depicted in this paper when resources are depleted and becoming scarcer then the situation is one of a reducing outcome game, which has never really been analyzed previously. This changes strategy as described by Kotler et al. [43].

If the game is not zero sums then the best result for everyone is obtained by collaboration rather than by competition. But it is always possible for one person to make a short term gain by competition¹⁴. In a non-zero sum game the strategies have been considered in an environment in which total payoffs can be increased; as a consequence in this game an increase in payoff for one player is not necessarily at the expense of other players. In the era of depleted resources however the total payoff is reducing and the payoff for each player is reducing without any competitive actions from the other players. Indeed competition raises transaction costs and thus reduces the resources available for production. Thus one firm might be able to increase production through competing for resources but globally the effect is a net reduction in resources available for production. The consequence of this is to give a big incentive to all players to improve their rewards at the expense of other players merely to stand still. Thus competition is engendered by the nature of the game and this makes it even harder for a collaborative approach to be introduced and worked successfully hence even more need for external interventions to manage the market place.

This presents a dilemma for the modern world. Economic theory and ideology shows that competition is the best way to expand both for an individual firm and through aggregation for nations and therefore ultimately for the world and all inhabitants. Thus development is considered to be desirable. Thus the modern economic model is based upon the Prisoners Dilemma scenario [44] whereby individuals gain

¹⁴ Strictly speaking the argument is that for best outcomes then a party should always adopt the strategy adopted by the other party in the last round. In a continuing series of games this leads to collaboration by default without the need to agree to collaborate.

advantage through competing with others. Indeed Amadae [45] argues that the whole foundation of neoliberalism is based upon Game Theory and particularly the Prisoners Dilemma, although others might argue that it is merely an extension of Utilitarianism. Nevertheless it is not to be disputed that this game is significant in aiding our understanding of the effects of resource depletion.

This kind of game has not however been considered and this demonstrates the limit of Game theory: either it is a zero sum game or it is an open game where the total rewards can be increased. It is argued in this paper that this is flawed because it does not represent the modern condition of the world. At present the environmental situation means that the available resources are shrinking (Hubbert's Peak etc.) because of the depletion of many natural resources. Thus the resources of the planet are shrinking as they become used and there are no more available for future economic development¹⁵. So it is necessary to extract the best use from shrinking resources this is the essence of sustainability. The game is not zero sum or increasing so new mathematics is required. For the new game which reflects the modern world and the availability of resources then there is a non-zero sum game where the total resources are actually shrinking. This is an extension of the game and requires new strategy for playing in this environment. From this it is possible to prove that the only way to get the best outcome in this new environment is through collaboration. So sustainability (and of course sustainable development) requires collaboration as competition no longer works. In games the participants are competitors and the success of one is usually at the expense of the other, such as when one firm gains market share through the use of an advertising campaign at the expense of the other firms in the industry. For the purposes of Game theory in such a situation the number of players can very often be simplified to two players the firm and the competition, with all competitors being regarded as a single player.

Game theory provides a method of formulating a business situation in terms of strategies – the strategy of the decision maker and the strategy of his/her opponent and in term of outcomes. Each player in the game selects and executes those strategies which (s) he believes will result in 'winning the game', that is will result in the most favorable outcome to the problem situation. In determining this strategy for winning each player makes use of both deductive and inductive logic and attempts quantification of the outcomes.

When cooperation takes place then often the benefits can be increased and then shared among the parties involved. How to share the benefits of cooperation has been the subject of much discussion and calculating the Shapley value to each party [46] is one well known method. The Nash cooperative bargaining solution [47] is another. It is necessary of course to make sure that collusion, and such illegal activity, does not take place: something which is likely to happen according to Smith [48]. On the other hand the tragedy of the commons [49], where common value is exploited to the detriment of all, must also be avoided. These two likelihoods also make it seem essential that some form of regulation is needed.

¹⁵ The economic system under which nations operate means of course that an individual firm can acquire additional resources through outbidding its competitors for the use of these resources. This naturally increases the cost of production and gives an imperative towards minimising the need to bid competitively for additional resources, but this nevertheless remains an option. But for the world economic system this is no longer an option so an alternative must be sought to enable development to take place. These two factors both tend towards the need to use available resources as effectively as possible – hence the need for the development of the game being undertaken in this paper.

Sustainability is a very new topic in business mathematics and there has not been a great deal of use of the technique of Games theory in addressing sustainability problems. It has been used [50,51] to consider water resource problems but mainly in the light of potential conflicts arising therefrom. It has also been used to consider carbon emissions [52] and carbon trading, again mainly for conflict resolution purpose [53]. At a broader level Vasile et al. [54] show that game theory can be used as a practical apparatus in providing additional information on the workings of the open market and on the dynamics in economic phenomena.

Here we argue that formulating this problem and a form of Prisoners Dilemma provides a different insight into the possible course of action. Thus it can be viewed as the options of one firm are to compete or to collaborate and these options are also available to the competition (who can be considered together as a consequence of summation) (Table 1).

	B (All competition)	
	Compete ab	Compete (1-a)b
A (The firm)	Collaborate a(1-b)	Collaborate (1-a)(1-b)

Table 1: Representation of basic zero sum game.

And it can be seen that

$$\Sigma = ab + (1-a)b + a(1-b) + (1-a)(1-b) = 1.$$

This is the basic game which is of course a zero sum game with the benefits being split between A and B according to which strategies they adopt and whether they collaborate or compete. Significantly they can only affect the division of the benefits but not the overall sum of the rewards. In a single zero sum game then the parties can benefit themselves through competition, represented. Thus:

For a single game:

$$ab > (1-a)(1-b).$$

For a series of games however this changes and the best strategy for either party is that chosen by their opponent in the previous game. As the number of games tends to infinity then this effectively means that the two parties are best to adopt a collaborative strategy, represented thus:

$$\Sigma_{-n} ab < \Sigma_{-n} (1-a)(1-b)$$

Where n=number of games in the series.

The significant feature of the Prisoners Dilemma is that each firm acting alone will seek to maximize their benefits through competition. Indeed the economic system upon which all markets are based expects competition. Further collaboration – which exists from time to time in the form of cartels – is generally specifically prohibited. This is even suggested by Smith (and all subsequent economists) to be unethical. From a global perspective however the collaborative approach

produces the best result and the preference becomes even more pronounced in the era of diminishing resources. This result however will never be chosen without some kind of external invention.

Carfi and Schiliro [55] consider the relative benefits of competition and cooperation in achieving environmental sustainability. They produce a model but do not resolve this through actual data. In some respects therefore this paper extends this work. Lozano [56] also considers sustainability in the context of stakeholders and examines different approaches taken for corporate social responsibility (CSR) and corporate sustainability (CS). He proposes a new typology aimed at providing a starting point to help detect where corporations are influencing, and where they could better influence, different stakeholders. Yang et al. [57] also consider sustainability but only in the context of human behavior aimed at security. Wooldridge [58] takes a broader perspective and considers whether games theory actually works. He concludes that it is beneficial in problem definition and the identification of pertinent factors. All of this research is just beginning to address the issue of sustainability by the application of game theory. Basically its effectiveness is identified and models are proposed but no empirical evidence is produced.

Empirical analysis

The analysis of the Prisoners Dilemma game shows that the only sustainable strategy is the one which should be chosen by both parties. In our case the parties can be considered to be one manufacturing company (requiring raw materials in depleted supply) and all of the competitors as the other party. The alternative courses of action are either to compete or to collaborate. Competing is the current business model and will lead to increasing transaction costs as supplies diminish while demand increases. The alternative of collaboration will only really occur if there is external intervention in the market through some form of governance and regulation. This too has a cost. Extensive analysis of the Prisoners Dilemma game shows that the best option is always to collaborate but that this choice is never made without external intervention [45]. While this is true it is necessary to consider at this point the relative costs of either competing or collaborating: in other words to consider how the costs of regulation in a new environment compare to the costs of increasing transaction costs as firms compete for ever more scarce resources.

Empirical analysis is needed to show the effects but this presents a problem. Costs of regulating a global market for scarce resources to ensure their optimum allocation simply do not exist and the best that can be achieved is to state that regulation costs less than 1% - for example Tobin [59] recommended 0.5% for his tax on financial transactions. In the USA it is claimed by the Washington Post that the cost of government regulation is \$1.75 billion, which it regards as excessive. But the GDP of the USA is \$15 trillion so this equates to 0.01%. Similarly the change in transaction costs resulting from competing for ever scarcer resources has never been identified in any accounting practices, not being recognized currently as relevant. Given that they will increase over time while regulation costs will remain constant then it is reasonably easy to see that they will eventually outstrip costs of regulation. Thus the intuitive result that collaboration is better than competition is supported by a reasonable analysis of available data. This is the best available result at the current time, especially as political involvement would intervene in any proposals.

Conclusion

This analysis, using Game Theory shows a different representation of the economic environment which will become more pronounced as resources shrink but demand continues to grow. It also shows that addressing this problem requires some kind of global approach and therefore enters the political arena, to be solved by some kind of intergovernmental approach requiring some form of global regulation. This of course is problematic but past evidence suggests that governments do act together when the need is apparent but often not until the last minute: the United Nations Framework Convention on Climate Change formed in 1992, but with a rocky existence ever since, provides one such example.

In order to use Game theory for this problem it has been shown that the theory has not yet been utilized to address the problem of resource depletion except by a few who consider the likelihood of war caused by competition for scarce resources [60]. None have considered any effect upon the economic model of firms' competitive behavior. Nevertheless it has been generally accepted that the prisoner's dilemma has become a fixed part of the repertoire of economic and social behavior [45] to such an extent that it is treated as a common sense approach to economic analysis [61-63].

Obviously there are a lot of factors which affect the decisions of a manufacturer concerning what goods to make and how to design both the goods and the processes for making these goods. Much of this is concerned with strategic decision making and is therefore relevant. Moreover given the situation of resource depletion and constraints on the availability of the raw materials then sustainability becomes central to the planning of production. This therefore is the subject matter of this paper which is concerned with planning a strategy in the changing environment in which people live. It is something that has not been explored in any depth and is both current and of increasing significance. The approach taken to the investigation of this topic is based primarily on the use of Game theory for investigation.

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