Applied Mathematics and Computation 265 (2015) 187–195

Contents lists available at ScienceDirect

Applied Mathematics and Computation

journal homepage: www.elsevier.com/locate/amc

# A mathematical model for the climate change: Can unpredictability offset the temptations to pollute?

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ARTICLE INFO

*Keywords:*
Climate change
Prisoner's dilemma
Evolution of cooperation
Stochasticity
Tragedy of the commons
Public goods

ABSTRACT

The climate change is an example of the biggest social dilemma in the human history. Climate change mitigation can be successful only if the whole world will undertake an internationally coordinated collective action. Costs to reduce emissions of greenhouse gases can be easily calculated for each individual, but benefits of the successful reduction will be distributed among all the "players", independently from their actual contributions to sustainable development. Evolutionary games provide a suitable theoretical framework for studying the challenges of climate change, and we will build on this fact in the present paper to study the evolution of cooperation and discuss its implications for offsetting the temptations to pollute. It has namely become painfully clear that tackling the climate change will be costly, and accordingly, the temptations to pollute will always be present. Can the element of unpredictability that is inherently present in social interactions and the environment increase the probability of adopting the cleaner strategy? We employ the spatial prisoner's dilemma game where the cooperative behaviour is challenged by defection that promises individuals a higher fitness and is thus more likely to prevail. Obtained results are contrasted with real data and indicators of climate change.



## 1. Introduction

Experiments on games capturing the essence of the social dilemma show that punishment can induce cooperation [2,8,9], but at the same time, it incurs costs for those who are executing the punishment, as well for those who are being punished. It is a combination of experimental economy and evolutionary biology [18]. How and when individuals are willing to cooperate has already been studied more than 300 years ago by Thomas Hobbes. He noted that, before the existence of governments, the problem of the egoistic individual prevailed. However, egoistic individuals at that time were competing under conditions when life was often solitary, poor, dangerous, cruel and short [12]. Cooperation based on reciprocity, on the other hand, can be initiated also in strongly defection-prone environments. It is very important that once cooperation in such environments is established, that it is also preserved [1]. In fact, reciprocal cooperation remains stable, if the future is more important than the present time. The reason is the time determinant, which allows both sides to wisely choose and deploy their strategies, *e.g.* one side decides not to cooperate and the other side has enough time to react accordingly. Importantly, of course, each individual

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http://dx.doi.org/10.1016/j.amc.2015.05.005
0096-3003/

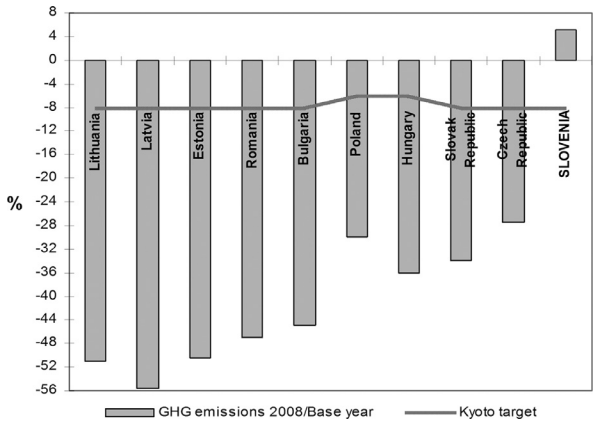


**Fig. 1.** Progress towards the Kyoto Protocol target for the new EU member states (EU-12) in 2008, without Cyprus and Malta (no emission targets set). Slovenia is the only state not fulfilling its Kyoto emissions target (marked with capital letters). All other new EU-12 member states are far below their Kyoto targets. The most successful, from the percentage point of view, is Latvia, yet Romania takes the first place from the quantitative point of view ([6,33]; and own calculations).

is in a better position only when all the participants will share the costs *and* the benefits of the global goods [28]. In game theory, which has been introduced to study frequency-dependent interactions, and in particular the evolution of cooperation as a specific example of such interactions, the prisoner's dilemma game captures succinctly the essence of the social conflict, and thus also the essence of the climate change dilemma. The so-called "climate game" focuses on a global good—the climate—yet not necessarily to maximise the profit, but rather to avoid the loss that could endanger the existence of future generations. The main problem is that the Earth is a global good that is shared by the entire population. Individuals are therefore not particularly prepared to invest in its protection, as it is very convenient and easy to assume that surely others will take care of it. But our climate is changing, indicating that too many of us are adopting this unfortunate reasoning as our own, and in fact we will soon be faced with a tragedy of the commons having enormous proportions [10]. Saving our climate is the biggest game we will likely ever play, and it is one we must not loose. We need to learn how to cooperate on a global level, how to respect the needs of others and how to avoid wasteful habits that imbue our lives. Insights from what promotes cooperation in evolutionary games, such as the prisoner's dilemma game, can help us to understand which are those factors that need to be considered in order to avoid a global meltdown. Studies show that groups are less prone to cooperation than individuals, mainly because to reciprocate in groups is challenging since it is difficult to determine who is most responsible for either the good or the bad performance. In many ways this is a problem that emerges due to lack of information and transparency, which is particularly common in large groups. Viable global climate agreements should of course allow variations in behaviour for each country, yet still focus in the direction of cooperation. The dilemma that naturally appears is: for how much should individual countries reduce their greenhouse gas emissions, and how much of this reduction should be done by developed countries and how much by countries that are in development? Based on a minimalist model entailing the spatial prisoner's dilemma game, we here outline a conceptual solution of the climate problem in the sense ensuring cooperative behaviour in large portions of the population based on fine-tuned levels of uncertainty in the strategy adoption process.

## 2. Kyoto Protocol and the mitigation of climate change

Climate change and the greenhouse effect are the two main subjects of the Kyoto Protocol, which was agreed upon in December 1997 by 160 countries in a town called Kyoto in Japan, where the third Conference of the Parties (COP-3) of United Nations Framework Convention on Climate Change [33] took place. The Kyoto Protocol can be described as one of the greatest international collective actions aimed at mitigating the climate change. Under the Kyoto Protocol, the Annex B parties agreed to reduce their overall greenhouse gas (GHG) emissions to at least 5.2% below the base year 1990 in the period 2008–2012. Some countries have agreed to even more rigorous targets, as follows: European Union (EU-15), Switzerland and Central-East European (CEE) countries have agreed to an 8% reduction, USA to a 7% reduction, while Japan, Canada, Hungary and Poland have agreed to a 6% reduction on average between 2008 and 2012 compared to base-year emissions. New Zealand, Russia and Ukraine need to stabilise their GHG emissions to the 1990 level. Some countries are allowed to increase their GHG emissions: Norway for 1%, Australia for 8% and Iceland for 10% [21]. Slovenia ratified the Kyoto Protocol on 21st of June 2002 and agreed to reduce GHG emissions to an average of 8% below the base year 1986 for the period 2008–2012 [32].

Unfortunately, Slovenia still remains the only new member state of the EU-12 that is not on track to reach the Kyoto target domestically [14]. Fig. 1 illustrates the distance to the Kyoto Protocol target for the new member states EU-12 in the year 2008 without Cyprus and Malta. The latter two namely do not have Kyoto targets. In Slovenia, GHG emissions in the year 2008 were for 5.2% higher than in the base year 1986. The Kyoto requirement for Slovenia is a reduction for 8%, which means that Slovenia is still far behind and it will thus not fulfil the GHG emission target with domestic measures.