Towards a System Dynamics Framework for Understanding Interactions of Head- and Tail-Users in Irrigation Systems in Kyrgyzstan

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Abstract

Irrigation and water supply systems are of vital importance for agriculture in many regions worldwide, especially in arid and semi-arid areas. However, over-abstraction of water and/or neglected maintenance are common problems faced by users and service providers. The paper outlines a conceptual framework for a dynamic model for collective irrigation management. Furthermore a preliminary causal loop diagram for the interaction of upstream- and downstream users is presented. The study builds on the results of a workshop with local participants in Kyrgyzstan on sustainable regional development and on the literature on collective resource management.

1 Introduction

Irrigation and water supply systems are of vital importance for agriculture in many regions worldwide, especially in arid and semi-arid areas. Farmer-managed systems have been shown to play a key role in irrigation (Vermillion 1998). Broad social anthropological evidence (Ostrom 1990, 1992; Lam 1998; Tang 1992) and theoretical insights derived from game theory (Baland and Platteau 1996; Runge 1992) have shown that collective property management can be considered as a rational and efficient institutional arrangement. However, opportunistic behaviour is a permanent challenge to collective irrigation management. Moreover, due to the physical asymmetry inherent in irrigation systems, users in the lower part of the system often complain about not getting their water share.

Conditions and design principles for successful collective action have been developed by several authors (Agrawal 2001; Meinzen-Dick and Knox 1999; Ostrom 1992, 1992a, 1999; Wade 1988). However, as pointed out by Agrawal (2001) there is a clear need for an integrated systemic approach with regard to collective action. This approach should take into account the heterogeneity of the users with regard to their interest as well as with regard to their assets (Runge 1992, Baland and Platteau 1996). Moreover it should be dynamic in order to reflect the dynamics of collective behaviour itself and the impact of ongoing socio-economic trends.

In this paper[1] we present a conceptual framework for a dynamic model on collective action and a preliminary causal loop diagram for the interaction of head- and tail-users in irrigation systems[2].

2 Method

The research method used combines participatory interdisciplinary research, theory-based conceptual work, and system dynamics modelling. In September 2005 a first workshop was held in the Kyrgyz village of Saz to develop a system dynamics framework for sustainable regional development. The participants of the workshop consisted of local farmers and inhabitants from various social classes, representatives of administrative bodies at village and district level, representatives of NGOs and researchers.

The conceptual framework and the preliminary causal loop diagram for the interaction of head- and tail-users are based on a review of the literature on collective action and

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[1] The study presented here is part of a research programme conducted by the Swiss National Centre of Competence in Research (NCCR) North-South. This programme aims at promoting sustainable development and mitigating syndromes of global change in collaboration with local research institutions http://www.nccr-north-south.unibe.ch

[2] The terms 'head- and tail-users' normally utilised in irrigation literature are equivalent to 'upstream- and downstream-users'.

irrigation management. Currently a dynamic model for collective irrigation management is being elaborated, which will be validated and further developed in a follow-up workshop in Kyrgyzstan in September 2006.

3 Problems and challenges[3]

The problem faced by farmers in Saz village – the sustainable management of irrigation water – is typical for many rural societies depending to a high degree on natural resources. The irrigation system in the village of Saz is composed of an upper part with main canals under the responsibility of the District Water Management Department, and a lower part with smaller distributary canals under the joint responsibility of the village administration and farmers. Water is abstracted from the Sokoluk river and directed through canals of different order towards the cultivated plots. Water fees have to be paid to the district administration, which is supposed to maintain the main canals. The fee covers only distribution services and maintenance, while water as such is (still) a good for free. Currently efforts are being undertaken to establish a Water Users' Association (WUA) in Saz, an endeavour that has not yet materialised.

Farmers in Saz are confronted with a variety of irrigation-related problems. High losses of water occur on different levels within the transportation and distribution system. In contrast to the general opinion of the farmers, research has demonstrated that the highest losses don't occur in the upper part under the responsibility of the district, but mainly in the lower part where both the village administration and the farmers are supposed to be responsible for maintaining the infrastructure. The difference in loss can be explained by two factors: (i) lower standard of the smaller distributary canals (earth instead of concrete canals), and (ii) the different levels of organisation. At the time only 20-25% of the total water abstracted from the river reaches the end of the system. Of the total loss of 75-80%, about 20% is lost on the upper (district) level and 55-60% are lost on the lower (village and farm) level.

The main problems and challenges, however, relate to institutional and social aspects. Due to a general distrust and dissatisfaction of many farmers with respect to the district administration, many decided to no longer pay the water fee to the district. Instead they agreed to elect a person responsible for the water distribution at community level called *murab*. In Saz this role was entrusted to a woman, who has been in charge of this key position for several years now. However, the financial transfers and the amount of water distributed through the *murab* are not fully transparent: 'Only the *murab* knows' was a clear open statement made by a farmer during the Saz Workshop 2005.

Despite the abundance of water, farmers at the tail end complained about getting insufficient water and also about not receiving it at the critical time needed. The general

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[3] This section is based on the results of the workshop in Saz in 2005.

payment behaviour of water users was openly discussed during the workshop. Participants widely agreed that about half of the farmers pay sporadically and/or only for part of the water received. While one participant clearly stated that he would only pay if he gets a sufficient amount of water at the right time and if the canals were kept in good condition, others seemed to be too poor to be able to pay any fee at all. This payment behaviour as expressed by the farmers is fully in line with research results obtained during field studies. Further discussions revealed that in order to achieve a more fair and equitable water distribution ethical and normative aspects had to be considered as well and that basic attitude towards society, nature, and administration should change profoundly.

4 Conceptual framework

4.1 Overview

In the last decades broad empirical and theoretical research has been carried out with regard to collective action and natural resource management. In order to develop an appropriate conceptual framework it is worthwhile mentioning various perspectives that may be adopted for the analysis of collective action with regard to the management of natural resources: institutional analysis and development (IAD), new institutional economy (NIE), participatory irrigation management (PIM), devolution of natural resource management, and game theory. Moreover, much research has been devoted to the synthesis of the findings on collective action and resource management. Although the overview presented here is not comprehensive it may provide a valuable starting point for the discussion of the conceptual framework. The overview is focused on aspects of irrigation and collective management.

Institutional analysis and development (IAD) focuses on the institutional arrangements on various levels, and the rules and incentives of the actors involved (Ostrom 1990); three levels of institutional analysis with regard to irrigation are distinguished: *operational rules* that directly affect the day-to-day decisions made by users and suppliers; *collective-choice rules*, which indirectly affect operational rules, used by irrigators, their officials, or external authorities in making management policies; and *constitutional-choice rules* determining (1) who is eligible to participate in the system and (2) what specific rules will be used to craft the set of collective-choice rules. Institutional analysis has been applied extensively to irrigation systems by Ostrom (1992), Tang (1992), and Lam (1998).

New institutional economy (NIE) takes into account (i) the role of transaction costs and relative prices promoting or hindering the evolution of new institutional arrangements (e.g. the transition from common property to private property) and (ii) the dynamic interaction between ideology, institutions, bargaining power, and organisations of groups of actors (North 1990; Ensminger 1992). The inherently systemic approach of the NIE might provide an interesting starting point for a system dynamics model.

Participative irrigation management (PIM), irrigation management transfer (IMT), and devolution of natural resource management is mainly inspired by the broad experience that user-managed irrigation systems often outperform agency-managed systems. Moreover the transfer of irrigation management from the state to user organisations is heavily driven by the intention of the government to reduce or eliminate subsidies for recurring costs of irrigation (Vermillion and Sagardoy 1999). Institutional arrangements, capacity building, and social mobilisation play a principal role in this approach (Vermillion and Sagardoy 1999, Ul Hassan and Nizameddinkhodjaeva 2003).

Game theory provides valuable insights in the variety of possible outcomes of situations where (groups of) players interact with each other (Baland and Platteau 1996). Games may have different forms (e.g. prisoner's dilemma, co-ordination game, assurance game) involving players with homogeneous or heterogeneous payoff structures. They may be played as one-shot games or repeatedly, with a small or large number of players. With regard to natural resource management in villages it is important to note, that situations, where the principle of reciprocity operates, are best characterised as "assurance games", not as prisoner's dilemmas (Runge 1992).[4] In assurance problems villagers benefit not only when everyone cooperates but also when a critical mass co-operates (Runge 1992, Baland and Platteau 1996). Thus a 'bad' and a 'good' equilibrium exist with threshold effects related to the critical mass of co-operating farmers.

> To avoid falling into the 'bad' equilibrium, a subgroup of players may decide to undertake the collective action in concert, regardless of what the others do. Here lies an important rationale for leadership and the function of the leader consists of mobilising a sufficient number of contributors rather than showing the good example as assumed in the previous section [signalling to the other his intention to co-operate] (Baland and Platteau 1996: 94).

Concepts of critical mass and thresholds in collective action have also been investigated by Granovetter (1978) and Oliver et al (1985).

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[4] It is worth mentioning here the 'tragedy of the commons' (Hardin 1968). Hardin's analysis refers to open access situations where no collective rules regulate the use of common resources. Therefore these situations can be described as Prisoner's Dilemmas (although more realistically as repeated Prisoners Dilemmas than by one-shot games). This perspective is not adopted here.

However, it has also to be noted that Hardin's final conclusions (Hardin 1968: 1247) are remarkably close to the findings derived by social-anthropological field research as he states that ''the social arrangements that produce responsibility are arrangements that create coercion of some sort', and continues that ''the only kind of coercion I recommend is mutual coercion, mutually agreed upon by the majority of the people affected' . This is fully consistent with the social-anthropological conclusions of Wade (1988) and Ostrom (1990, 1992).

4.2 Conditions and design principles for successful collective action

Several authors present an overview of conditions or design principles for successful collective action (Agrawal 2001; Meinzen-Dick and Knox 1999; Ostrom 1992, 1992a, 1999; Wade 1988). Ostrom (1992: 44) with reference to Wade (1988) and Uphoff et al. (1990) summarises that motivation to engage in collaborative action on established irrigation projects is highest

> … where (1) farmers have long time-horizons, (2) they face sufficient scarcity that they are motivated to invest in organising themselves, and (3) they are assured that organisation could make a substantial difference in their yields.

While points (2) and (3) are also captured by a suggested curvilinear relationship (Tang 1992), point (1) needs more careful interpretation. Baland and Platteau (1999) note that the structure of the users' time preferences determines whether strategies, which yield more immediate results or strategies aimed at resource conservation will be adopted. These variations in time horizons are related to the distribution of wealth with two extremes leading to a discount of the value of the future income through the flows from the common property resource. On one hand the low level of wealth of the poor may not allow him/her to participate in collective action or to undertake conservation measures even though such actions would permanently increase future income. On the other hand better-off households with access to outside economic opportunities tend also to overexploit the resource as they anticipate a shift to alternative occupation and hence don‘t have a long time horizon any longer. For very poor households this is a difficult situation as they often most directly depend on the resource, hence should pay most attention to conserve the resource. Moreover, their strong intention to minimise risks might also motivate them to preserve the resource as much as possible. Hence, following Baland and Platteau (1996) two opposite effects have to be considered: dependence on the resource and level of resource base (economic capacity to invest in the long-term conservation of the resource).

Thus the heterogeneity of the actors has to be considered carefully (Olsen 1965; Runge 1992; Baland and Platteau 1996, 1999). The distinction made by Baland and Platteau (1996) and Agrawal (2001), which point to the difference between heterogeneity with regard to endowments and with regard to interests, is of special importance. Whereas heterogeneity in endowments and assets does not necessarily impede collective action - it even may support collective management - heterogeneity of interests may cause rapid (over-) exploitation of the common resource. This is due to the fact that some groups (e.g. absentee owners) may have attractive exit strategies motivating them to exploit the resource as quick and as much as possible.

Further parameters that determine farmers' motivation for collective action are: reliability of water supply, equity, and fair rules. 'Fair' rules are those where the benefits gained and the costs (labour, financial input) are in an agreed balance (Ostrom 1992). Mc Kean (1998) stresses the fact that distribution of decision-malting rights and use rights to co-owners of the commons need not be egalitarian but must be viewed as ‘fair’ (one in which the ratio of individual benefit to individual cost falls within a range they see as acceptable).

It has also been pointed out that having a common history in collective action (either with regard to irrigation or to other fields) supports further successful collective action. This common history is also referred to as social capital (Ostrom 1999, Agrawal 2001).

4.3 Attitudes

According to Schiffman and Kanuk (1996) attitude can be defined as ’a learned predisposition to behave in a consistently favourable or unfavourable way with respect to a given object’. This definition emphasizes that attitudes persist across time and vary only slowly. They can be viewed as a construct that precedes and determines behaviour and thus guides choices and decisions for action.

The basic understanding of attitudes adopted for this study is demonstrated in Figure 1. Attitudes guide the users’ actions, which consist in water abstraction, payment or non-payment and (eventually collective) maintenance efforts. The outcome of these actions - ultimately the amount of water farmers get compared to what they perceive as being fair – feeds back to their attitudes and may change these over time according to modified experiences. Both processes influence each other finally leading to a modified perception of what is considered as being a ‘fair’ share of water and a ‘fair’ payment for a service received.

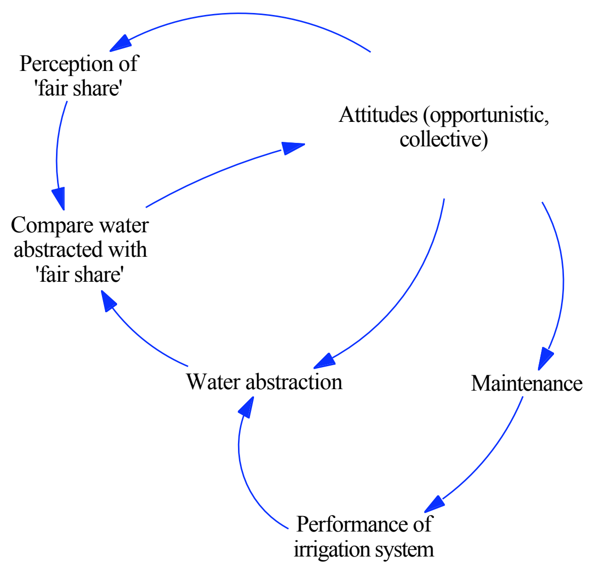

Figure 1: Feedback structure capturing the relations between attitudes, actions, perceptions, and the performance of the irrigation system.

4.4 Scope of the model

Objectives

The objective of the model is to derive a framework for understanding the dynamics of collective management in small irrigation systems taking into account (i) asymmetries between head- and tail-users, (ii) feedback effects related to the performance of the system, (iii) socio-economic stratification of the users (poor, medium, and rich farmers), and (iv) diversification of income generating activities.

By means of this framework two questions will be addressed:

- What strategies improve the performance of irrigation systems?
- Does the envisaged Water Users' Association (WUA) contribute to this improvement, and under what conditions?

Hypothesis

Although mechanisms for collective management being in place it is hypothesised that the ongoing trend of diversification tends to further deteriorate the irrigation system. It is further hypothesised that by strengthening enforcement mechanisms and by introducing transfer payments for poor households (from rich households and/or from government) this trend can be attenuated and eventually reversed.

Institutional level

The analysis mainly focuses on the level of operational rules, assuming that certain institutional rules are in place. Hence it is neither attempted to model the change of rules nor is the point of view of the NIE adopted here, although this approach shows considerable common ground with system dynamics (Atkinson 2003). It is assumed that collective action mechanisms are in place.

The question is therefore, how a commonly managed irrigation system will evolve over time taking into account feedback mechanisms between the performance of the irrigation system and the changing livelihood strategies. However, aspects of bargaining power have to be kept in mind when determining the relationship between head- and tail-users.

Terminology

According to the Dictionary of Sociology (Marshall 1998) 'collective action' is defined as: 'action taken by a group (either directly or on its behalf through an organization) in pursuit of members' perceived shared interests'. Opportunistic behaviour may consist of free riding, rent seeking, and corruption or of combinations of these types of behaviour (Ostrom 1992). For the purpose of the model 'opportunistic behaviour' is considered to be free riding only. The other two aspects would require taking into consideration a larger system boundary, which would be beyond the scope of the model.

Model boundaries

In terms of space, the boundaries of the model are determined by the water supply system of a village. The discrepancy between administrative boundaries and 'natural' (biophysical) boundaries given by the watershed itself, although happening quite often, are neglected in the model. With regard to institutional arrangements the model focuses on local decision-making and thus on operational rules. The model applies to the situation of the village Saz in the Sokoluk river basin in Kyrgyzstan.

Time horizon

The time horizon of the model is 1995 to 2020. Starting in 1995 takes into account the political disruption, which occurred in 1991 through the independence but avoids being too close to the upheaval itself. Twenty-five years appears as a reasonable time-horizon for irrigation infrastructure.

5 Results: Preliminary causal loop diagram

The basic causal loop diagram (Figure 2) proposed in this paper describes the interaction between head- and tail-users. The socio-economic stratification and the diversification of income strategies are not yet taken into account. The causal loop diagram consists of ten loops that are described in the following section.

The behaviour of head- and tail-users is described by a word of mouth structure (R3, R5) that captures the fact of critical mass and thresholds in collective action mentioned above (Granovetter 1978, Oliver et al 1985, Runge 1992, Baland and Platteau 1996). However, the perceived performance also determines the decision of the users.

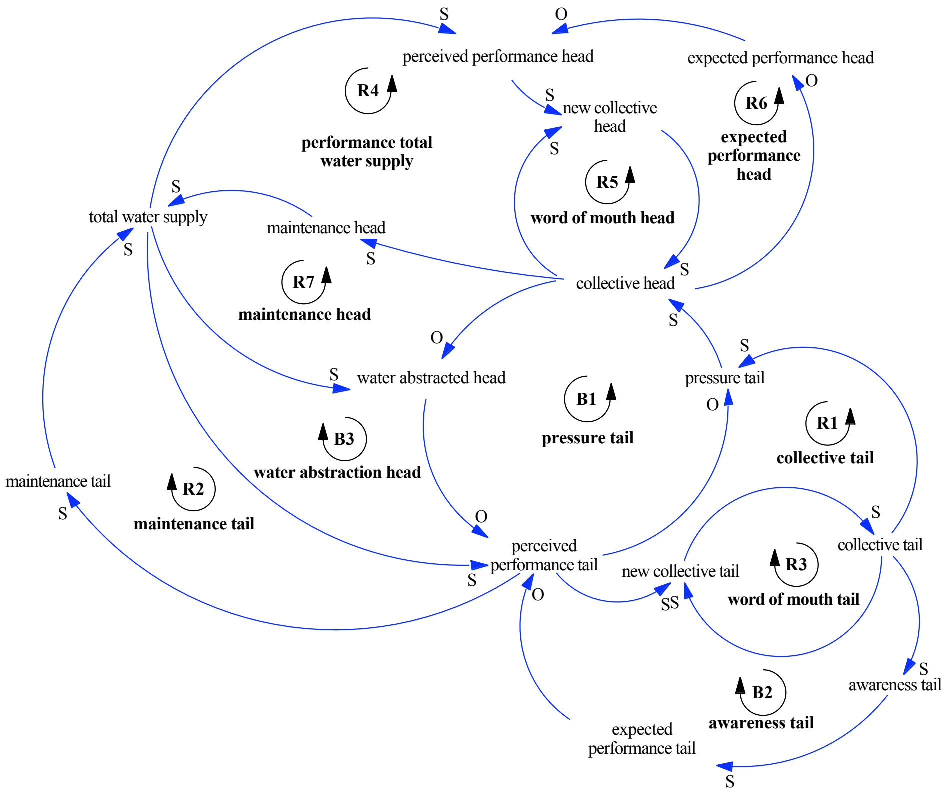

Figure 2: Feedback structure in an irrigation system with head- and tail-users.

The interaction between head- and tail-users is provided by three effects: (i) pressure is exerted by tail-users in case of low perceived performance (B1) and/or a high degree of internal organisation (R1); (ii) maintenance is effected or neglected depending on perceived performance tail (R2) or on the level of collective action head (R7); and (iii) water abstraction of head-users determines perceived performance tail (B3).

Pressure tail loop (B1) is a balancing loop describing the response of the head-enders to increasing pressure of the tail-enders. The head-enders will behave more and more collectively, reduce their water abstraction and increase their payment and maintenance share. This will increase the perceived performance of tail-enders. It has to be stated though that this loop only works if head-enders have to concede the pressure of tail-enders. Bichsel (2006) reports a situation in Kyrgyzstan, where tail-enders - though being well organized - could not get their agreed share of water and instead of further pursuing their claim dug a proper parallel canal beside the existing one.

Maintenance tail loop (R2) is a reinforcing loop describing the basic fact that the willingness of the tail-enders to maintain the irrigation system depends on the water they are allowed to abstract. Mc Kean (1998) points out that 'an important key to the cohesiveness of farmer-managed […] irrigation systems is the power of tail-enders to withhold their labour from maintenance of canals, channels, etc […] when they feel that head-enders are taking too much water'. Unlike the tail-enders, who are in the weaker position, the head-enders' willingness to contribute their maintenance is assumed to depend strongly on the level of collective action head (R7).

The effect of over-abstraction by the head-enders is captured by the water abstraction head loop (B3), which results in a reduced perceived performance of the tail-enders.

Awareness tail loop (B2) refers to the notion of a fair share of water to be released by the head-enders. As mentioned above the distribution of use rights need not to be egalitarian but must be viewed as fair by the users. This fair share is denoted here as expected performance of tail users. However, to know about the fair share requires sufficient awareness, knowledge and information of the tail-enders about the irrigation system, especially about the total water supply, the amount of irrigated land of head-users and tail-users, as well as the maintenance and/or payment done by all the members of the irrigation system. Liniger et al. (2005) reports the experience in the upper Ewaso Ng'iro basin in Kenya, where the tail-enders began to exert pressure against the head-enders only after they had recognized what the amount of the total water supply in reality had been. They became aware that the water scarcity they experienced was not due to climatic variation alone but mainly to upstream water abstraction.

Total water supply determines the performance experienced by tail- and head-users and the amount of water that head-users potentially may abstract.

The word of mouth structure introduced above is incomplete in so far as it captures only transitions from opportunistic towards collective action, but not vice versa. A more comprehensive word of mouth structure that takes into account transitions in both directions is presented below (Figure 3). In order to avoid a cluttered structure it has been left out in the Figure 2.

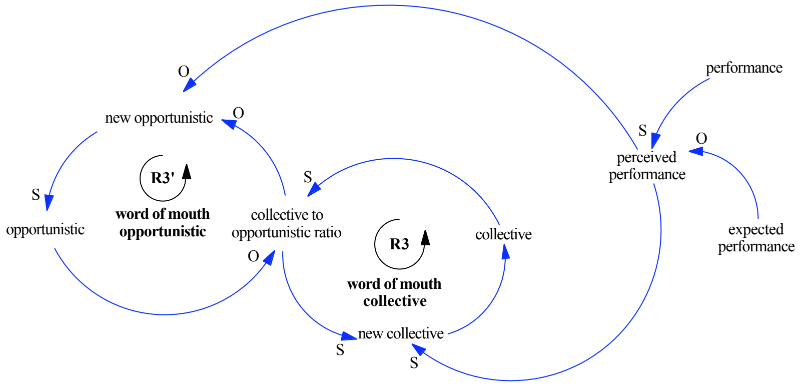

Figure 3: Word of mouth structure capturing transitions from opportunistic to collective action and vice versa.

6 Discussion and outlook

The causal loop diagram presented here has to be considered as preliminary with regard to the elements that have been taken into account. Important conditions for successful collective action such as dependence on the resource, heterogeneity in interests and assets and their change over time, socio-economic stratification and the effect of changing income strategies have not yet been integrated. However, it facilitates the discussion of basic processes related to irrigation and collective action and provides a starting point for further modelling.

From a methodological point of view the research project has demonstrated that close interplay of participatory research in the field and in depth study of available theoretical work is needed in order to derive a meaningful model concept. Through combined efforts in field research and in modelling aimed on one hand at establishing a clear understanding of the empirical context and on the other hand at providing a dynamic synthesis a contribution towards an integrated view of collective action could be provided. In order to verify and enrich the understanding of the processes, it is planned to hold a follow-up workshop with local participants and experts in Kyrgyzstan bearing on the structure presented here. Furthermore the workshop is aimed at providing empirical information about key variables identified in the model.

In order to investigate the dynamics of collective irrigation management it is envisaged to develop a quantitative threshold model of collective action that refers to the processes elucidated in the causal loop diagram presented here. Further mechanisms that have been enumerated above will be integrated and their dynamic implications will be examined.

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