Threats to sustainability: simulating conflict within and between nations

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Abstract

Violent conflict is increasingly viewed as a factor related to sustainable development. This article argues, based on the well-established theory of lateral pressure originally proposed by Choucri and North in 1975, that the relationship arises because the same factors that affect sustainable development also influence conflict, namely population, technology, resources, military force, and trade and bargaining, while conflict, in turn, affects these variables. The theory is tested with a system dynamics model that includes international as well as domestic violent conflict, calibrated to seven countries in southern Africa and six OECD countries. The results show a number of situations in which conflict is perpetuated in a cycle that is difficult to break. © 1998 John Wiley & Sons, Ltd.

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Security, sustainability, and violent conflict

Increasingly, matters related to security and stability are recognized as relevant to sustainable development. This recognition is especially salient when conditions of insecurity and instability threaten the potential for transition toward sustainability. Moreover, security and sustainability may be related to the extent that they are both shaped by the same underlying demographical parameters, technological conditions, and resource endowments rooted in socio-economic, ecological and political processes, which all interact together to shape environmental balances.

Wars and warfare often divert valuable energy and resources away from social goods and economic investment (relative shares of military versus civilian expenditures) and concentrate national policies on 'defense' matters rather than on sustainability trajectories. Most recently, this general awareness has taken on a new form, namely the concern expressed in both academic and policy-making circles about dual but distinct dilemmas: environmental consequences of conflict and conflicts generated by environmental deterioration (Choucri 1997; Barbier and Homer-Dixon 1996). The problem, of course, is

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lateral pressure theory, first formulated by Robert C. North, since 1970 and has published numerous books in this area, as well as many articles on econometric and system dynamics models.

that the causes and consequences of conflict are highly interconnected, and the interconnections are likely to be greater when the conflicts become more violent.

The problem

This paper takes as its task to address the broad problem of 'untangling' sources and consequences of conflict, by formulating, testing, and reframing a system dynamics model based on the theory of lateral pressure to facilitate our understanding of these entanglements.

Specifically, we present a system dynamics model of violent behavior at the national level which is characterized by modeling:

1. linkages among *internal* sources of external activities;
2. factors leading to *internal stress* and propensities for transforming these into lateral pressure;
3. alternative paths for *intervening processes* that mediate between sources of violence and potential consequences of conflict;
4. connectivity paths to *external conflict*;
5. the 'feedback' implications of external conflict on *internal conflict*.

The model is used for simulating behavior paths for a selection of 13 countries at different levels of development with different underlying attributes and parameters. These range from number of poor, weak countries in Africa, to stronger, more affluent countries in Europe and North America. In each case, we predicate our analysis on empirically derived parameters.

The approach

While recognizing the persistence of disagreements in both the scholarly and the policy community about the nature of conflict, its underlying sources, and attendant consequences (described clearly, for example, in Brecher 1996), this paper views conflict and violence as rooted in the complex constellation of interactions among human needs and wants, on the one hand, and natural systems and ecological conditions, on the other. This broad perspective allows us to frame a set of propositions (to be formulated in system dynamics terms) representing a causal logic of conflict and violence. Work by Choucri and North (1975), Choucri and Bousfield (1985), Choucri, North and Yamakage (1992), and Choucri and Berry (1995) embodies a set of papers on lateral pressure theory paraphrased in the next section. Other, related, publications that are examples of models including interactions among natural and/or social systems to understand conflict and violence are those by Shantzis and Behrens (1973), Saeed (1994) and Homer-Dixon (1994). An overview of this literature is provided in more detail in Kamiya and Wils (1998). Lofdahl's (1997) quantitative study shows the ways in which environmental degradation 'expands' spatially, thus generating a range of international consequences.

The theory

This paper is guided specifically by the theory of lateral pressure initially formulated by Choucri and North (1975). The original theory was articulated in econometric terms. This paper follows the theoretical tradition of lateral pressure and develops further some less formalized facets of the core theory through applications of system dynamics logic and modeling.

The basic theory of lateral pressure argues that the roots of conflict can be traced to the constellation of needs and wants of populations, given levels of technology and the availability of natural resources. If resources are limited relative to population demands and technology levels, the country will expand its behavior outside national boundaries. Lateral pressure refers to the propensity for extension of behaviors outside territorial boundaries—in various behavioral models, or 'paths', associated with different propensities for conflict and violence. The 'causal connections' are not direct, but mediated through a complex array of intervening processes (and variables) that, jointly shape the alternative trajectories of actions which may, or may not, result in overt violence. The challenge is to identify the nature of the intervening processes—relating demands and needs to strategies for meeting those needs—as well as the conditions under which different outcomes prevail and the various 'paths' connecting 'causes' to 'consequences' (Choucri, North and Yamakage 1992).

The objectives

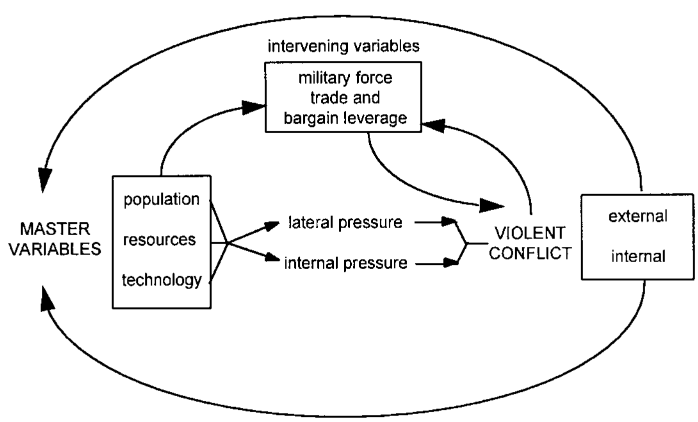
Our specific objectives are twofold. First, we contribute to the theory of lateral pressure by differentiating between *internal stresses* that generate internal conflicts and those pressures that generate *external expansion* and which may then follow trajectories leading to international conflict and violence. Second, the dynamic feedback relations, which are presented more 'qualitatively' in other studies of lateral pressure, are modeled explicitly in system dynamics terms and their significance is explored with simulations.

As such, the objective of the paper differs slightly from that of many system dynamics models, in that it aims to contribute to an existing theory as well as to provide seeds for policy thought.

The propositions

The problem we address is this: since 'everything' is related to 'everything else', how can we best formulate the causal connections between internal stress, external behavior, and patterns of violent conflict. We put forth a way of thinking about these relationships and a model to explore the robustness of our logic. For convenience, we present first a simplified view of the overall model, in Figure 1. To clarify the implications of the linkages at hand, we put forth a number of propositions that represent the causal logic in terms of dynamic feedback relationships. Subsequently, we discuss matters of data and measurement, and, finally, present simulations.

Fig. 1. Basic structure of the integrated model

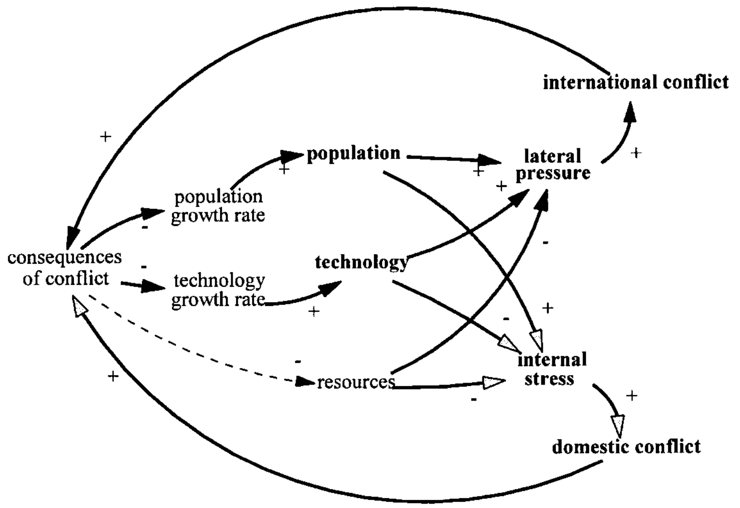


The propositions are rooted in the theory of lateral pressure and taken from it. The interested reader can refer to one of the references cited above for a further discussion. In this section, the results of the extensive analyses contributed by the lateral pressure theory, with the extensions on internal tension and conflict feedback, are paraphrazed briefly. The section 'Model and measures' goes into more detail.

Proposition set 1

The first proposition is that *the constellation of the master variables—population, technology, and resources—provides the basic impetus which sets in place the causal 'mechanisms' that contribute to the eruption of violent conflict, and that wars change the relative values of the master variables*. This proposition is articulated through a set of six feedback loops, shown in Figure 2.

Fig. 2. The six core loops encompassing the master variables—population, technology, and resources—internal tension and lateral pressure, domestic and international conflict, and the consequences of conflict on the master variables.



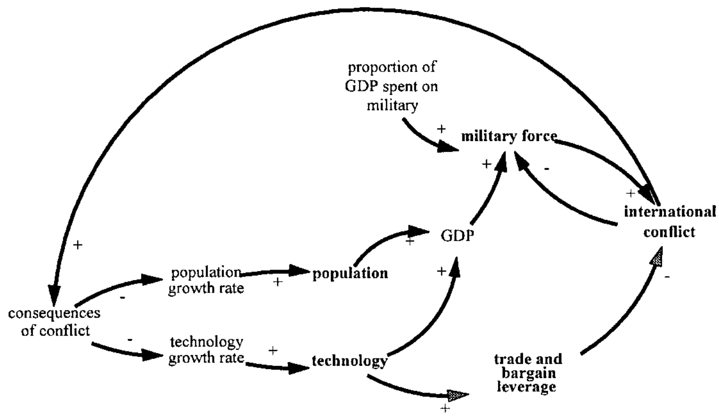
Population growth and technology growth both increase lateral pressure, which leads to more international conflict, to greater consequences of conflict and lower population and technology growth. Resources reduce lateral pressure, international conflict and the consequences of conflict. Theoretically, the consequences of conflict reduce resources, but this relationship is not implemented in the present model. For internal tension, population increases internal tension while technology and resources reduce it. Internal tension increases domestic conflict, which leads to greater consequences of conflict and reduces population growth (creating a balancing loop) and technology (creating a reinforcing loop).

The black loops, i.e. with black arrowheads, show the relationships for international conflict. According to the theory of lateral pressure, population and technology are positively related to lateral pressure, which increases international conflict; in turn, conflict and violence reduce the prevailing growth rates of population and technology. By contrast, the theory states that natural resources are negatively related to lateral pressure, which reduces international conflict, but that if conflict occurs, the consequences negatively influence natural resources; this results in a reinforcing feedback loop. The gray loops i.e. the loops with gray arrowheads, show relationships for internal tension. Population increases internal tension, which leads to more domestic conflict, and the consequences reduce population growth. On the other hand, technology reduces internal tension, and, going around the conflict loop, this reinforces technology. The same is true for natural resources.

Proposition set 2

The second set of propositions related to the *role of intervening processes or variables*, and ways in which they may affect propensity for international

Fig. 3. Military force loop and trade and bargain leverage loop.



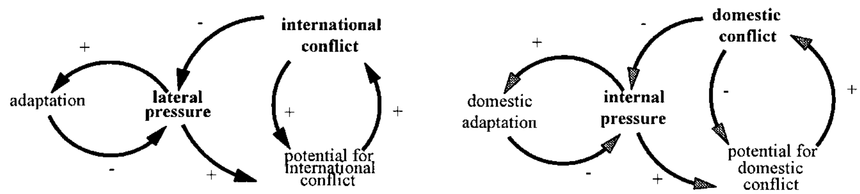
Population, technology, and the proportion of GDP spent on military increase military force, which leads to more international conflict, to greater consequences of conflict, and lower population and technology growth rates. International conflict also reduces military force. The level of technology leads to greater trade and bargaining leverage, which reduces international conflict and the consequences of conflict, thus reinforcing technology growth.

conflict. Such processes include military build-up (which increases the likelihood of 'paths' to violence) or trade, negotiation, and bargaining (which represent less violent ways of access to resources), both shown in Figure 3.

The military build-up itself is modeled in terms of a balancing feedback relationship. Military expenditure is taken as a user-defined proportion of real gross national product (following Choucri and Bousfield 1985). Thus, when the gross national product increases, absolute military expenditures rise also (a country which spends 5% annually on the military will spend more in absolute terms when GDP is $500 billion than when GDP is $300 billion). The higher expenditures accumulate in greater military force. Enhanced military force, in turn, increases the probability of conflict. Military force is drained through depreciation of obsolete weaponry, *plus*, *during a conflict*, a portion of the stock of military force is used up annually thus draining the stock faster. Furthermore, conflict, if it occurs on national territory, reduces GDP.

According to the theory of lateral pressure, trade and commercial interactions can serve as intermediary variables that temper the tendency towards violent conflict. Trade and commercial interactions are involved in a reinforcing feedback relationship. Trade is positively influenced by the level of technological development; and it reduces the probability of conflict. The lower the level of conflict, the more positive are the implications for increased technological development.

Fig. 4. Feedback loops belonging to the conflict and pressure propositions.



There is a negative feedback between adaptation and pressure; a negative feedback between conflict and pressure; and a reinforcing feedback between conflict and the potential for conflict.

Proposition set 3

The third set of propositions pertains to the dynamics of conflict itself. These are derived from the theory of lateral pressure, but the formulation used here is novel. First, as lateral pressure and internal tension increase; there are *internal feedback* mechanisms of adaptation that reduce the potential for conflict. Second, while violence acts as a pressure release valve, it also *increases the risk of continued violence*, creating the possibility of a spiral of violence. These are shown in Figure 4.

This, then, completes our propositions. The next section discusses in greater detail the role of the master variables in the generation of lateral pressure and internal tension.

Model and measures

Master variables

The entire logic begins with the master variables. Population numbers are simple: numbers of people. Both technology and resources have, by necessity, been simplified. The approach to measures of natural resources and technology are discussed further below.

Basically, the master variables population and technology change exponentially in this model, and the growth rates are a function of user-defined exogenous default rates of change *and* the effects of conflict. For example, say the user defines default population growth rate at 0.015 in a given year, but there is also a conflict. Then the conflict reduces the population growth rate by some measure which depends on the intensity of the conflict. The same is true for technology change. The formulations used in this paper do not include a model with endogenous demographic change or development. Conceptual models of endogenous demographic change are as old as Condorcet (1795) and continue through the demographic transition theory (Notestein 1945) to modern research, for example Wils (1996). System dynamics has a tradition of endogenous technological change and development, beginning with, for example, Meadows and Meadows (1973) and continuing through to Acharya and Saeed (1996). More recently, neo-classical economics has also embraced endogenous technological change, following the model proposed by Romer (1990). In light of this literature, it may appear that exogenous change is over-simplified; however, we justify it on the following grounds. First, we can experiment with a wide range of growth assumptions, or adhere to assumptions that are widely accepted (such as the medium population projections provided by the United Nations). Second, the emphasis of this paper is on the dynamics of conflict, and these dynamics emerge from the growth assumptions as formulated. Third, endogenous population and technological growth is not addressed as that would engender a lengthy discussion on the merits of particular model specifications, and thus distract from the subject of the paper.

Technology

Technology is one of the key variables relating human activities to the environment. The sophistication and the type of technology used in a particular society determine which natural resources are useful and exploited; and to what measure. As the level of technology increases, the number of resources and the intensity of use increase also (Choucri 1995). This has two effects. The first is that the total need for natural resources rises. The second is that the dependence on a specific natural resource, such as land, declines.

This dual effect explains the paradoxical nature of technology. Technology has been the key to releasing humanity from the Malthusian trap predicted by Malthus in 1798, because it has enabled a release from the dependence on a specific resource, namely land. Presently, technology is called upon to solve many of the environmental problems caused by an intense use of specific natural resources (Wils, 1998). Yet, technology has also increased our use of natural resources overall, including the use of the environment through pollution.

The dual effect of technology is reflected in the specifications for lateral pressure and internal tension discussed below. While the tendency for technology to increase the overall need is expressed in lateral pressure; the effect of reducing dependence on the specific resource, land, is reflected in internal tension.

Even when the duality problem is solved, there remains the issue of how to operationalize technology. In this paper, we have chosen to use GDP, or purchasing power parity (a measure of GDP adopted for local prices), following earlier studies in lateral pressure.

Resource measures

We stress that our use of resource availability refers to a multi-faceted notion—it consists of land area, quality of land, mineral and fossil-fuel reserves, water quantity and quality, and many other aspects. Moreover, each level of technology requires a different set of natural resources. Thus, where a country may have had enough land for a society dependent on traditional agriculture, the same nation may find itself short of the fossil fuels necessary for industrialization at a later period. Concurrent with evolving technology, the value of natural resources changes over time; for example, two centuries ago the oil in the Middle East was worth practically nothing, whereas now it is the source of enormous wealth.

To reflect the many aspects of natural resources, one would like to have a composite natural resource variable. For example, it could consist of: total land area; land area that is actually and potentially arable; the value of mineral and fossil reserves; water resources; and so forth. Unfortunately, of these variables, only total land and the value of mineral reserves were found in consistent form among global data sources (World Resource Institute, World Bank).

If we were to include a complex resource variable, which consisted of say, arable and potentially arable land, as well as mineral reserve value, then we might expect some changes in simulations for certain countries. For example, the resource base of countries in the Middle East would increase drastically in the beginning of this century, as the value of fossil fuels rose and reserves were discovered, but might begin to decrease as the reserves are diminished. Alternatively, the resource base of China might decline as its arable land base is eroded.

However, in the absence of an integrative strategy for combining these various elements, a simplified approach is unavoidable. Therefore, following earlier work on lateral pressure, total land area has been taken as a proxy for natural resources. While this is supported by Kindleberger (1962) and endorsed by North (1990), we recognize that this term is basically a proxy, not a precise representation of the resource notion.

The selected 13 countries that are used in the simulations below are all fairly well endowed with natural resources. Arable land is a high proportion of the total land area in all cases, but it is highest in the European countries and two of the African countries, Rwanda and Burundi. The mineral reserves of the United States and the African countries, except Rwanda and Burundi, appear to be ‘large’ (World Resources Institute 1994). Thus, we might find, in our particular selection, that the results obtained by using land area do not differ greatly from those that would be found using a more complex variable.

Lateral pressure and internal tension

Lateral pressure (LP) refers to expansion of behavior to areas outside the national borders. Following the discussion in Choucri and North (1975; 1993), and Choucri and Berry (1995), this paper argues that lateral pressure can be generally expressed as a function of the number of people and the level of technology, in relation to the set of domestic resources. The following logic applies: each person, at each level of technology, requires a certain amount of resources. The general equation for lateral pressure is then written as:

$$\mathrm{LP} = f\left(\frac{T \cdot P}{R}\right) = f\left(\frac{\mathrm{ResourceNeeds}}{\mathrm{ResourceAvailable}}\right), \quad (1)$$

where LP is lateral pressure, T is the level of technology, P is the population, and R is natural resources, and which will be further specified below.

We develop an important addition to the earlier lateral pressure theory by specifying internal tension that generates internal disruptions. This contribution stems from the notion that the same material variables that cause lateral pressure can also be factors of internal destabilization, as posited by, for example, Homer-Dixon (1994) and Saeed (1994). There are numerous forms of conflict that do not necessarily result in behavioral manifestations of external violence—independence movements, civil strife and revolutions are expressions of conflicts that emerge from *internal tension*.

The formulation for internal tension in this paper draws upon the population density emphasis found in arguments presented in anthropology (Cohen 1984) and economics (Boserup 1968). Such arguments state that as population density relative to resource base rises, societies need to change their technological and social base, in general towards higher levels of complexity and sophistication—by devising intensified agricultural methods, industries, class differentiation, and such. High levels of population density and high levels of technology can result in internally stable societies, if access to resources is assumed; conversely, low population density requires only low levels of technology for stability. Then, the proposed arrangement for internal tension (IT) is:

$$\mathrm{IT} = f\left(\frac{P}{R} \cdot \frac{1}{T}\right) = f\left(\frac{\mathrm{PopulationDensity}}{\mathrm{Technology}}\right). \quad (2)$$

However, a simulation model requires that the theorist be very specific about formulation. In preparatory work for this article, an analysis of global data on population, technology, and resources, Wils (1997) showed that the best way to operationalize lateral pressure would be:

1. To incorporate *diminishing marginal contribution* from technology, population, and resources;
2. To *normalize* the variables;
3. To include an *internal dynamic of adaptation* for lateral pressure and internal tension.

The argument for diminishing marginal contributions makes sense with the following reasoning: each person, unit of resource, or unit of wealth contributes to the constellation of lateral pressure or internal tension, but, with increasing numbers, the incremental contribution of one more unit declines. In the idiom of economic literature, one might call this the 'decreasing marginal contribution to lateral pressure' of each master variable unit.

To operationalize such diminishing returns, one seeks a concave function, such as a square root, or a logarithm—and the choice of function should be determined by calibration. Experiments with the model showed that a square root function for the master variables appeared to be robust. Thus, the following form of the lateral pressure equation is:

$$\mathrm{LP} = f\left(\frac{\sqrt{T}\cdot\sqrt{P}}{\sqrt{R}}\right). \tag{1b}$$

On this basis, we then formulated the equivalent equation for internal tension.

The normalization of the variables is done by dividing technology, population, and resources by a *tech unit*, *pop unit*, and *res unit* respectively, so that the units of each of the contributing master variables are dimensionless. A *pressure unit* is added to the equation to reflect lateral pressure (see Appendix).

So far, lateral pressure and internal tension are formulated as a *function* of the square roots of the master variables. In the following section, the particulars of the functions are discussed.

Adaptation vs. accumulation

We assume that lateral pressure and internal tension accumulate over time, and society may adapt. The logic is the following: the master variable constellation generates a certain value for annual internal tension. This stress factor is added to feelings of stress from earlier periods, which have not been successfully 'ingested'. Thus, a country that suddenly experiences a temporary increase in population, or a brief deterioration of the environment, will not immediately erupt into conflict—this would happen only if the population or resource change is long-term and pressure arising from th new master variable relation accumulates.

Societies may find ways of gradually adapting to such accumulations of strain. These may induce a society to adapt in the form of technological and social inventiveness. This situation is described in Boserup (1968) in reaction to increasing population pressure. Such adaptation is not necessarily successful. It can be too slow relative to the changes in population or the deterioration of the environment, so that pressure accumulates in spite of social attempts to cope. Examples of this would be found in areas with rapid change in population size and/or environmental deterioration. Also, the adaptation could be unsuccessful simply because it is inappropriate. For example, in some areas land and water are eroded and polluted as a result of highly mechanized agriculture. Further, as signaled by the laws of thermodynamics, such adaptation cannot continue indefinitely. In this model, the assumption is made that, on average, the adaptations are reasonable and are conducive to reducing the pressure from the master variable constellation, and further, that within the time horizon of the model, adaptations are still possible. A certain time necessary to adapt is included. Depending on the relative rates of change of the master variables, and on the adaptation time, lateral pressure and internal tension can increase or decrease over time. The time necessary to adapt is taken to be the length of one generation, or 25 years. The adaptation is subtracted from the cumulative pressure build-up.

We can thus see lateral pressure and internal tension as two stocks, each with an inflow resulting from the constellation of the master variables and with an outflow that is some proportion of the present pressure level. With these considerations, the proposed equations for lateral pressure and internal tension have the following form:

$$\begin{aligned} \mathrm{LP}(t) &= \mathrm{LP}_{\mathrm{initial}} + \int_{t_0}^{t} \left(\frac{\sqrt{T} \cdot \sqrt{P}}{\sqrt{R}} - \frac{\mathrm{LP}(t)}{\mathrm{AdaptationTime}} \right) \mathrm{d}t \\ &= \mathrm{LP}_{\mathrm{initial}} + \int_{t_0}^{t} (\mathrm{LP}_{\mathrm{change}} - \mathrm{LP}_{\mathrm{drain}})\, \mathrm{d}t \end{aligned} \tag{3}$$

$$\begin{aligned} \mathrm{IT}(t) &= \mathrm{IT}_{\mathrm{initial}} + \int_{t_0}^{t} \left(\frac{\sqrt{P}}{\sqrt{R}} \cdot \frac{1}{\sqrt{T}} - \frac{\mathrm{IT}(t)}{\mathrm{AdaptationTime}} \right) \mathrm{d}t \\ &= \mathrm{IT}_{\mathrm{initial}} + \int_{t_0}^{t} (\mathrm{IT}_{\mathrm{change}} - \mathrm{IT}_{\mathrm{drain}})\, \mathrm{d}t, \end{aligned} \tag{4}$$

where '*AdaptationTime*' is the time necessary to adapt to changes in the master variables. From this formulation, one can see that, if a country experiences rapid changes, the level of lateral pressure can rise or decrease, whereas, if the changes are slow, lateral pressure and internal tension may remain constant or decline.

Simulation design

Reference expectations and alternative 'paths'

On the basis of the above theoretical considerations, a number of reference expectations were formulated in lieu of the more conventional reference modes. The two most obvious expectations are:

1. the higher lateral pressure, the higher the international conflict involvement;
2. the higher internal tension, the more domestic conflicts.

It is also expected that some countries may experience an oscillatory conflict cycle where periods of peace alternate regularly with warfare. Oscillations are due basically to the delays and balancing feedbacks associated with the following loops: population and technology growth lead to lateral pressure and internal tension, as well as military force accumulation, which increase the probability of conflict. Conflict in turn, serves to dampen population, technology, the military force, and, with a delay, the probability of continued violent conflict.

Thirteen countries were selected for simulation. These countries present a wide range of master variable values. The historical paths of the master variables and military expenditure are reproduced in the model for the selected periods, namely 1950–1990 for OECD countries, and 1960–1990 for African countries. For the base simulation, the effects of military force, trade and bargaining, the consequences of conflict, and the annual drain of military force in the case of a conflict are calibrated so that the simulation results for the largest number of countries reproduce the conflicts experienced in the historical period.

In the following sections, the results of the base simulations are discussed, in light of 'correct' (reflecting history) simulations for conflict as well as those which are 'incorrect'. The results are pertinent to the interpretation of the general relevance of our original propositions. In addition, a number of simulations addressing attempts to reduce conflict frequency are presented and discussed.

Case analyses

The simulation analyses are pursued with respect to two groups of countries. One group includes Angola, Botswana, Burundi, Mozambique, Rwanda, South Africa, and Zambia. Africa has experienced much domestic conflict and the high rates of population growth, low levels of technology, and much of the continents's proneness to droughts make it the logical focus for this type of study. The second group consists of wealthy countries in Europe and North America: France, the UK, Germany, Sweden, the Netherlands, and the United States. These countries are on the far end of the technology spectrum; they also have the most sophisticated military forces in the world and are leaders in global trade.

Table 1 shows the 13 countries arranged by population density (high and low density), an important variable for internal tension, and wealth (high and low level of technology), significant for both lateral pressure and internal tension. There is an even distribution of the four cells, which indicates that there is a good distribution of master variable constellations in our selection. Table 2 gives a brief description of key features of each country.

Empirical context

The master variable data are drawn from the World Resources Institute 1996–7 Database Diskette (1997). On that diskette, the population variables are from United Nations sources; technology level is approximated by purchasing power parity in constant dollars (drawn from the Penn World Tables); land area data are from the World Resources Institute. Military expenditures for OECD countries are from the CIA World Fact Book (1997). The violent conflict data, which are being continually updated, have been gathered from multiple

Table 1. Selected case countries, with conflict years (D = domestic conflict; Intl = international war)

	High population density	Low population density
Low level of technology	Burundi (Intl 1972–79; D 1988) Rwanda (D 1994)	Bowswana Angola (Intl 1961–91) Mozambique (Intl 1976–92)
High level of technology	Netherlands (Intl 1947–51) France (Intl 1951–53; 1952–56; 1953–55; 1954–62; 1955–56; 1991) Germany United Kingdom (Intl 1948–53; 1950–53; 1956; 1963–67; 1963–64; 1982 (Falklands); 1991 and D 1969–92)	United States (Intl 1950–53; 1958; 1961–65; 1964–73; 1965; 1966–92; 1979–84; 1982–94; 1989; 1991) Sweden South Africa (Intl 1961–92)

Table 2. Brief description of thirteen countries selected for simulation

Country	Description
AFRICA	
Angola	Angola has low per capita income and population density. The country is rich in natural resources including oil, diamond and gold. The economy is heavily dependent on oil production. Angola has had one short and one long international conflict during the years 1975 and 1992.
Botswana	Botswana has a relatively high per capita income as an African country and has a very low population density. With its poor land quality, the country is highly dependent on its diamond industry. Botswana has not been in any active conflict since 1945.
Burundi	Burundi is a resource-poor country with low per capita income and high population density. Presently, almost all the potentially arable land in the country is being cultivated. Burundi has been in two domestic conflicts in the 1970s and 1980s.
Mozambique	Mozambique is a country rich in agricultural land, and water resources. It has low per capita income and medium population density. From 1964 to 1975, Mozambique fought for its independence. Furthermore, from 1976 to 1992, Mozambique was engaged in one long domestic conflict, in which one side was supported by South Africa.
Rwanda	Rwanda is similar to Burundi in that it is a resource-poor country with very high population density and low per capita income. Population growth has been in excess of 3% annually since 1960. Rwanda was engaged in one domestic conflict during the early 1960s, and there was a domestic massacre in 1994.
South Africa	South Africa is a resource-rich country with relatively high per capita income and higher population density than neighboring countries. Since 1945 and during the period of apartheid, South Africa was involved in two domestic conflicts and three international conflicts. It is by far the strongest country in the region in military and economic terms.
OECD	
France	France is a rich country with medium population density. The country has a modern economy and is particularly rich in its agriculture resources. During the de-colonization period (1945–1975), France was engaged in seven international conflicts.
Germany	With its unification in 1989, Germany is still in its transition period. Germany is relatively poor in natural resources, but its economy is well developed with its world-class service and manufacturing sectors. It has high per capita income and population density. Germany has not been in any active conflict since 1945.
The Netherlands	The Netherlands is a densely populated country. Its economy is modern and heavily dependent on trade and financial services. Its social system is well developed. During the 1950s and 1960s, the Netherlands was engaged in two long international conflicts, namely Indonesia and Korea.

Table continued on page 144

Table 2 (*continued*)

Country	Description
Sweden	Sweden is a country with a high level of technology, that is sparsely populated and rich in natural resources. It has for decades kept its neutral stand in the international community and internally maintained high living standards with extensive welfare benefits. Its economy is highly dependent on trade and financial services. Sweden has been engaged in neither international nor domestic conflict since 1945.
United Kingdom	The UK is a rich country with large natural reserves and relatively high population density. Its economy is well developed with notable strengths in its service, energy production and agricultural sectors. During the de-colonization period and the Cold War, UK was engaged in a few international conflicts. Furthermore, during 1969–1992, there was a domestic conflict in N. Ireland (with the IRA).
United States	The USA is sparsely populated and rich in resources, including arable land and various mineral resources. It has the most powerful and technologically advanced economy in the world. During the Cold War (1949–1989), as one of the principal actors, the USA was engaged in various international conflicts (Vietnam, Korea and the Gulf War).

sources, such as Bloomfield (1997), and Singer and Small (1982). The time horizon of the simulations is long—one hundred years—to follow such slowly changing variables as population and even level of technology. The simulations start in 1950 or in 1960, depending on data availability.

For purposes of analysis, the base run for each country is calibrated to the historical changes in its master variables, military expenditure around 1990, and the historical level of actual domestic or international conflicts.

Baseline simulation input

The values for the salient *input variables* of the baseline simulation are presented in Tables 3–4. Each of these tables consists of three columns: *the country*; *column A with initial values of parameters*; and *column B with base simulation values of parameters*.

Column A shows values for the beginning of the historical period, namely land area (*R*), purchasing power parity (*T*), population (*P*), and the values for lateral pressure change (LPC) and internal tension change (ITC). LPC and ITC represent the immediate source of pressure resulting from the actual constellation of the master variables. They are the inflow to the stocks of lateral pressure and internal tension (see above in the section on ‘Lateral pressure and internal tension’).

Column B shows the changing values of the master variables and the intervening variables for the baseline simulation. The baseline simulation for

Table 3. Initial conditions and growth values, plus uncalibrated baseline scenario input for African countries. Explanation of symbols used in the table found in cells for Angola. A 'ramp' means an annual increment in the *rate of growth*, from year *A* to year *B*, written as 'ramp' (increment, *A*, *B*)

Country	Initial values (Column *A*)	Scenario values Column *B*)
Angola	Population (P) = 4.816 million	Annual population growth rate (ΔP) = 0.02% 1960–90 and declines to 0 by 2050
	Technology level (T) = 0.931 PPP in 85 dollars per person × 1000	Annual technology growth rate (ΔT) = 0.02% annually except in conflict years
Resources	(R) = 1246 × 1000 km^2	
	$\text{LPC} = \dfrac{\sqrt{P}\cdot\sqrt{T}}{\sqrt{R}}$, (LPC) = 0.06	Military expenditure (ME) = 0.03% of total national purchasing power parity.
	$\text{ITC} = \dfrac{\sqrt{P}}{\sqrt{R}}\cdot\dfrac{1}{\sqrt{T}}$, (ITC) = 0·06	Trade and bargain leverage multiplier (TBL) = 2.5 Military force effect multiplier (MFE) = 0.5
Botswana	$P = 0.480$ LPC = 0.02 $T = 0.535$ ITC = 0.04 $R = 582$	$\Delta P = 0.03$ declining to 0.006 by 2050 $\Delta T = 0.07$ from period 1960–80, then 0.02 ME = 0.03; TBL = 2.5; MFE = 0.5
Burundi	$P = 2.941$ LPC = 0.26 $T = 0.64$ ITC = 0.41 $R = 28$ (effective $R = 56$)	$\Delta P = 0.027$ + ramp (−0.0003, 50, 100) $\Delta T = 0.0$ ME = 0.03; TBL = 2.5; MFE = 0.5
Mozambique	$P = 7.461$ LPC = 0.32 $T = 1.153$ ITC = 0.28 $R = 784$	$\Delta P = 0.022$ declining to 0.012 by 2050 $\Delta T = 0.0$ 1960–95 except 1975; then 0.03 ME = 0.03; TBL = 2.5; MFE = 0.5
Rwanda	$P = 2.742$ LP = 0.23 $T = 0.537$ IP = 0.42 $R = 24$ (effective $R = 48$)	$\Delta P = 0.03$ declining to 0.01 by 2050 $\Delta T = 0.0$ ME = 0.03; TBL = 2.5; MFE = 0.5
South Africa	$P = 17.396$ LPC = 0.59 $T = 2.191$ ITC = 0.27 $R = 1221$	$\Delta P = 0.03$ declining to 0 by 2050; $\Delta T = 0.02$ ME = 0.03; TBL = 2.5; MFE = 0.5
Zambia	$P = 3.228$ LPC = 0.06 $T = 0.963$ ITC = 0.07 $R = 743$	$\Delta P = 0.03$ + ramp (−0.0004, 50, 100) $\Delta T = 0.0$ ME = 0.03; TBL = 2.5; MFE = 0.5

each country is composed of an historical and a future simulation. The historical baseline is the one that reproduces the historical results for master variable change and the military expenditure. In the baseline future, land area is constant. The rate of future baseline population change follows the well-respected scenarios for population growth into the next century published by the United Nations (1995). Our base simulations replicate the fractional population growth rates as they are projected in the UN's medium version (the UN also produces a high population and a low population projection). There do not exist, to the authors' knowledge, similar projections for the growth of GDP or purchasing power parity per capita and the authors are left with their own best judgment. A decline in the growth rate of GDP per capita is assumed for the wealthy OECD countries. For the base future simulation of the poor countries in Africa, GDP or PPP per capita growth rates are kept constant after 1990.

Table 4. Initial conditions and growth values, plus uncalibrated baseline simulation input for OECD countries. Symbols as in Table 3

Country	Initial Values (Column A)	Scenario values (Column B)
France	$P=40$ LPC = 0.54	$\Delta P=0.008$ declining to 0 by 2050
	$T=4$ ITC = 0.13	$\Delta T=0.03+$ ramp (−0.00036, 1990, 2050)
	$R=550$	ME = 0.03; TBL = 2.5; MFE = 0.5
Germany	$P=70$ LPC = 0.77	$\Delta P=0.005+$ ramp (−0.0001, 2000, 2050)
	$T=3$ ITC = 0.26	$\Delta T=0.047+$ ramp (−0.0006, 1975, 2050)
	$R=357$	ME = 0 + step (0.02, 20); TBL = 2.5; MFE = 0.5 initial military force ≈ 0
Netherlands	$P=10$ LPC = 1.10	$\Delta P=0.012+$ ramp (−0.00024, 2000, 2050)
	$T=4.5$ ITC = 0.25	$\Delta T=0.033+$ ramp (−0.0004, 1990, 2050)
	$R=37$	ME = 0.023; TBL = 2.5, MFE = 0.5
Sweden	$P=7$ LPC = 0.32	$\Delta P=0.006$ declining by 0 by 2050
	$T=6$ ITC = 0.05	$\Delta T=0.028+$ ramp (−0.00033, 1990, 2050)
	$R=450$	ME = 0.026; TBL = 2.5; MFE = 0.5
United Kingdom	$P=51$ LPC = 1.06	$\Delta P=0.003+$ ramp (−0.00006, 2000, 2050)
	$T=5.3$ ITC = 0.20	$\Delta T=0.03+$ ramp (−0.00036, 1990, 2050)
	$R=245$	ME = 0.037; TBL = 2.5; MFE = 0.5
United States	$P=150$ LPC = 0.37	$\Delta P=0.011+$ ramp (−0.0002, 50, 100)
	$T=9$ ITC = 0.04	$\Delta T=0.022+$ ramp (−0.00024, 1990, 2050)
	$R=9809$	ME = 0.053; TBL = 2.5; MFE = 0.5

Note that fractional growth rates are subject to ramps, which indicate *linear change in the fractional rates*. Although the fractional growth rates may decline, the absolute values of growth clearly would not.

Column B also shows: military expenditures as a percentage of GDP (ME); the parameter values for the level of trade and bargaining culture or leverage (TBL), the default level of which was calibrated to 2.5; and the military force effect (MFE), which has a default level calibrated to 0.5. These parameters can vary from country to country, but in the baseline simulation, the default values are used. These variables reflect that even, given equal potential levels of trade and bargaining power or military force, different countries may have varying social propensities to engage in activating these mediating variables. The parameter levels have no cardinal value; they are relative terms which can be used to compare countries and simulations. Variations from these base-run values are explicit in the discussions of alternative runs below.

Simulation results

African cases

Conflicts in Africa have been well publicized over the past several decades. But some African countries have had continuous peace, at least since 1945. Most of the conflicts have been domestic, although in part fueled by third nations. South Africa is a notable exception—this country was involved in numerous conflicts outside its borders. A predominance of domestic conflict would suggest that population density, or the growth in population density, is not in balance with the level of technology. It might also indicate that there is instability associated with recent independence, as Gledditsch (1997) suggests, or that borders are drawn without regard for tribal groups. Although such factors may well play an important role, a rigorous test of the master variables hypothesis would be to measure the extent to which conflict can be differentiated in terms of its dominant features, namely associated with internal tension.

We focus primarily on countries from the southern region of Africa, based on the assumption that, as a result of greater cultural homogeneity and geographical proximity, differences in conflict level would not be readily explainable by such things as 'cultural propensity for warfare'. Moreover, this region offers a wide variety of countries—the small, densely populated Rwanda and Burundi; large empty places such as Angola and Botswana; and a more industrialized nation, South Africa—which cover the lateral pressure and internal tension scale for developing nations.

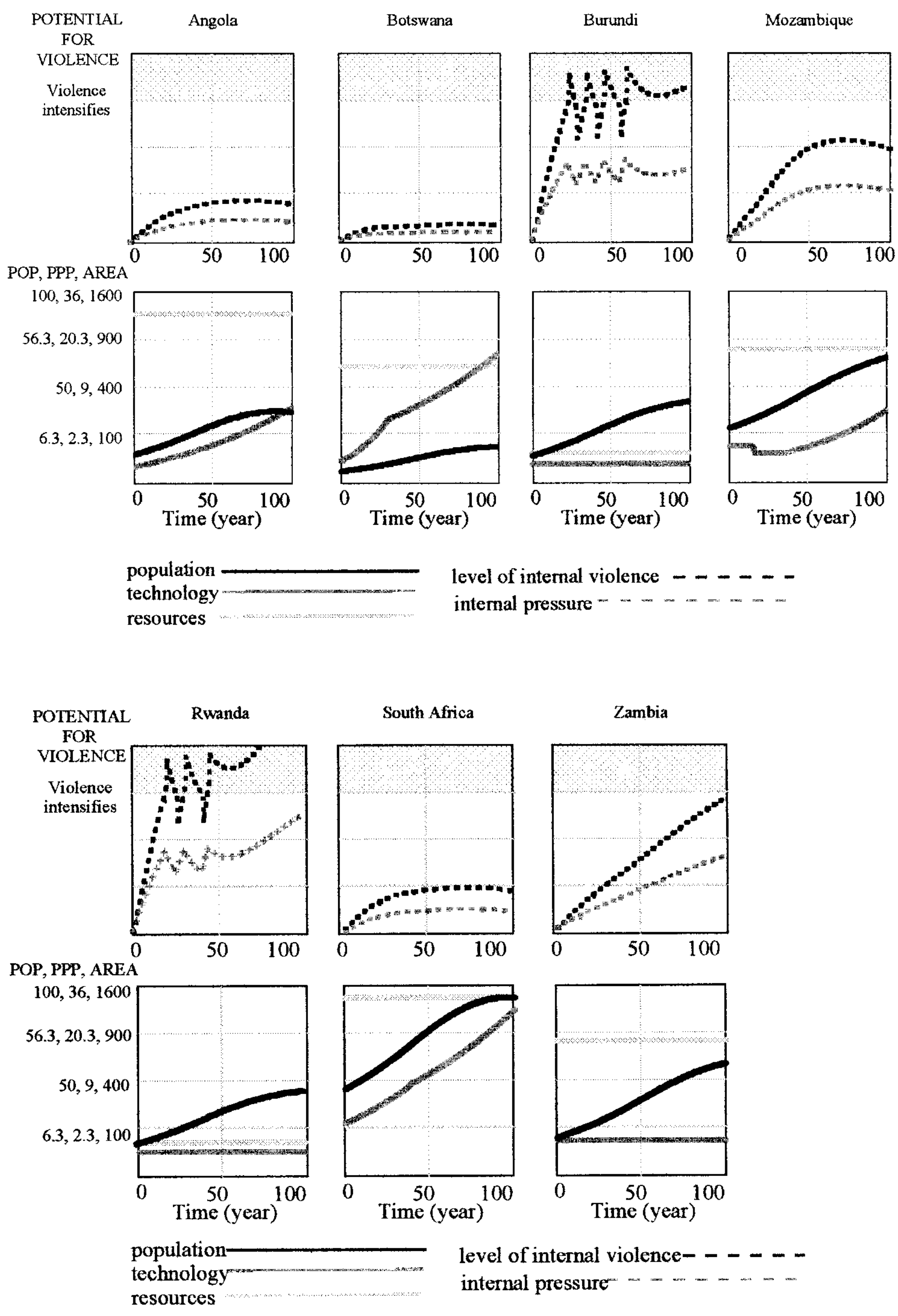
The initial values for the master variables and growth rates for purchasing power parity (PPP) and population are shown in Table 3. The results of the base runs are in Figure 5. The baseline values for MFE and TBL are assumed equal for all countries in the selection. Thus, all differences in conflict level arise from the material base formed by the master variables and the intermediate variables.

Consistent with the historical record, the simulations for Botswana and Zambia show no conflict. By contrast, the simulations for Burundi and Rwanda produce multiple eruptions of domestic conflict due to high values of internal tension in the simulations, as has historically been the case. The high internal tension in the latter two countries occurs in spite of the high proportion of arable land in these countries. To reflect the value of this land, the value of resources is doubled.

South Africa has relatively high lateral pressure and internal tension, exacerbated by poor trade relations (in the era of Apartheid) and relatively weak military neighbors. However, the multiple conflicts which that country was involved in (two domestic and three international from 1945–1990) are only replicated if extremely high values of the military force effect (level 3 as opposed to default level 0.5) and high multipliers of internal tension change (level 3 as opposed to default level 1) are implemented.

Further, with the calibrated values for the intervening variables and the historical values for the master variables, the model produces no conflicts for

Fig. 5. Baseline simulation results for seven selected African countries.



Angola and Mozambique—the internal tension values, particularly for Angola, are very low. These results are contrary to the wars experienced in these countries. The model suggests that the conflicts in Angola and Mozambique are not due to the constellation of the master variables, which is much like that for Botswana and Zambia. In these two cases, other factors, such as the intervention of a third country (in these cases, South Africa), may have led to the eruption of conflict. Other possible causes of the wars in these countries could be domestic power structures and/or cold-war politics, or the lateral pressure effects of both countries' large neighbor, South Africa.

In terms of the 'predictive' value of the master variable constellation for internal conflict, this small sample says that a high level of internal tension may be *sufficent* cause for conflict, but that a low level of the same is *not sufficient* for the avoidance of conflict.

To complement these baseline simulations, we experimented with changes in population and technology growth, value of resources, propensity to trade, and military expenditures to reduce levels of conflict. These experiments reveal how the consequences of conflict feed back into the factors that cause and perpetuate conflicts.

In the case of Rwanda and Burundi, the simulations illustrate that it is difficult to 'opt out' of a conflict situation which has its base in the constellation of master variables. This is because the master variables and pressure variables (which might express themselves in the form of ethnic rivalries) have considerable momentum and change only slowly. In one simulation, population growth was instantly switched to zero in the model year 2000. This immediate reduces internal tension change. However, actual internal tension, which is the accumulation of decades, only decays slowly. Therefore, conflicts continue, although at a less frequent rate. Moreover, in fact, the high population growth rates in Burundi and Rwanda cannot be instantly turned off—this is contrary to what we know about population age structure and growth momentum. In simulations with reduced population growth—for example to zero by the simulation year 2035—there is almost no effect on the internal conflict frequency.

The results show that violent conflict also reduces the growth rate of technology. This impact, in turn, has a tendency to prolong domestic conflicts—because lower technology leads to higher internal tension. However, once a conflict is terminated (or halted), technology growth can increase, thus forestalling further conflicts. Simulations for Burundi, in which the extrinsic technology growth rate is raised from 0.00 annually to 0.06 annually in the model year 2000 (when no conflict is simulated), decrease conflict, but even this extraordinary level of growth does not eliminate conflicts altogether in the simulation period. Each incremental increase in technology growth serves to reduce conflict years. However, the effect is less than linear (a change in growth from 0.02 to 0.06 reduces the number of conflict years by less than a factor of three). This is because the higher technology level also allows the military force to grow. This causes the conflicts to be considerably more destructive, and this destructiveness cuts more deeply into technology than a smaller military force could. The same is true for simulations with Rwanda.

The picture for the future of Burundi and Rwanda, *within the context of this model*, would indicate that an increase in the level of economic growth (through international cooperation, or regional growth) could reduce, but not eliminate, conflict in these countries in the next decades. However, such specific statements are premature and a closer analysis of these countries would be advisable. For now, the model has given some useful insights into the momentum and dynamics that probably exist in these countries.

European cases

The model logic suggests that, in contrast to Africa, the OECD countries, with their high levels of technology, should have fewer or no internal conflicts. At the same time, however, the high levels of technology and large military forces keep the OECD countries' levels of lateral pressure high, which indicates more international conflicts.

The OECD countries modeled are France, Germany, the Netherlands, Sweden, the UK, and the United States. The data (see Table 2) show that, since World War II, the selected European OECD countries have not been involved in domestic or international conflicts on their own soil—except for the UK, where since 1969 there has been the dispute in Northern Ireland. This, however, masks the fact that many of these countries were involved in international conflicts overseas. In particular, the 1950s and 1960s were periods of multiple conflict for the UK, France, and the Netherlands, mostly wars of decolonialization. Since that period, even these countries have not been involved in international conflicts. Germany and Sweden have not been involved in any international conflicts since 1950.

Further along we focus on the results for the US case. Here, however, we note that a slightly different pattern is evident. The United States also has not experienced international conflict on its own soil. It has had multiple long and short non-decolonialization international conflicts abroad, extending into the present period. In fact, since 1945 the USA has been involved in a greater number of conflicts than any other OECD country.

Table 4 lists the initial values and growth rates for the master variables, as well as military expenditure rate (ME), military force effect, trade and bargaining leverage multiplier, formulated as discussed above.

Figure 6 shows the simulation results. For the Netherlands, France, Germany, and the UK there is a high level of lateral pressure, which increases over time, caused by growing population densities, but particularly by ever higher levels of technology. However, the probability of violence remains low and there are virtually no international conflicts in the period from 1950 to 1990 shown in the simulations. Actually, the colonialist countries were involved in wars of independence during th 1950s and 1960s (see Table 2). These cannot be reflected because of the initial conditions of lateral pressure. Initial lateral pressure (simulation period 1950) is set at zero. We know, of course, that lateral pressure was probably greater than zero. However, without historical simulations tracing further back in history, we cannot say how great the accumulated lateral pressure was in that year and we make the simplest choice. By 1965 or 1970, the simulated lateral pressure has accumulated sufficiently to reflect the actual circumstances better. The long period of peace following 1970 is reflected in the simulations, in part due to a high engagement in trade and bargaining, which follow from the high levels of technology.

Germany and Sweden are shown to have no international conflicts in the historical period, which reflects the actual facts. For Germany, this is in spite of high levels of lateral pressure. In the simulation, the initial German military force is zero (as it was in 1950) and military expenditure is also zero. Without a military force, no international conflict is possible. Sweden, on the other hand, experiences no conflict because of its low level of lateral pressure, combined with a relatively small military force.

The US case

Out of our selection, the country that was historically engaged in the most military conflicts in recent history is the USA. The military conduct of the USA is not due to high lateral pressure—in fact the lateral pressure level is about equal to that of Sweden. According to specifications of the model, one cause for the high engagement of the USA in international conflict could be its extremely large military force. The large military force is a product of the large economy and the high military expenditure rate. However, even that is not enough to reflect the actual number of conflicts. With the trade and bargaining parameter, TBL, and military force effect set equal to the level of the European countries, the simulated number of international conflicts for the USA would be half of what it was historically.

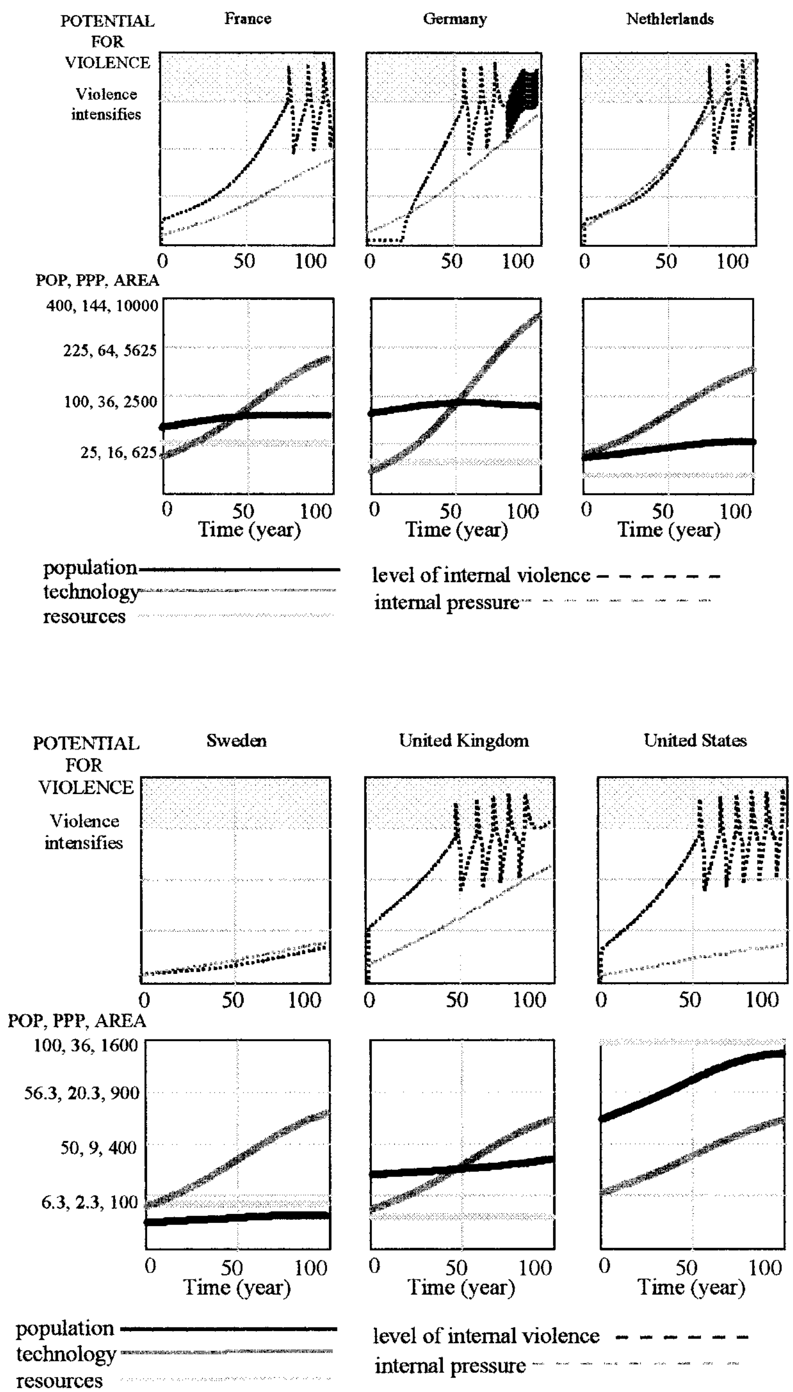


Fig. 6. Baseline simulation results for six selected OECD countries.

There are three plausible reasons that the USA might be involved such a high level of conflicts: one is material and two are political, all of which can be simulated. The two political are a low trade and bargaining level, and a high military force effect. If the former is halved, or the latter is doubled, then the conflict level is equal to that which was historically observed. The material cause could be the very high consumption of raw material in the USA (exemplified by its high energy consumption per capita and dollar income), which would raise lateral pressure. To simulate this resource intensity, a resource intensity proxy was introduced into the lateral pressure and internal tension change variable in the following manner:

$$\mathrm{LPC} = \frac{\mathrm{ri} \cdot \sqrt{T} \cdot \sqrt{P}}{\sqrt{R}}, \tag{5}$$

where ri is the resource intensity. Doubling the resource intensity of the system increases the level of conflict to that observed historically.

From this study, we cannot conclude which reason causes the high level of American conflict involvement. Is it the ‘soft’ political variable trade or the military effect? Or the material need for resources? Or is it another influence not considered in this model? Given that the high consumption of raw goods in the USA is a quantifiable fact, there is an indication that this might play a significant role.

Comparative inferences, OECD countries

If this analysis is extended into the future, the simulations suggest the USA continuing to be involved militarily abroad, but also, more frequently, the European countries with high lateral pressure. Inferring from the US history, this involvement would not be on European soil (as were the two world wars in this century), but rather would be overseas. In short, the dynamics of the model would indicate that in the next decades, some European countries might be more willing to join the US in international conflicts such as the Gulf War than they were in the past, motivated by mounting lateral pressure.

What changes would reduce conflict in the simulations of OECD countries? In order to simulate continued absence of international conflict and maintain growth of technology (population growth declines to zero), in the selected European countries, a higher engagement in trade and bargaining, lower military expenditures, or a reduction in the need for resources would all suffice, according to the model.

To reduce the simulated level of US conflict, lower military spending (for example, to 2% of GDP by the year 2020) eliminates only a fraction of the conflicts. This result is due in part, first to the momentum inherent in a stock of weapons, second because, with fewer conflicts, military force is dissipated more slowly, and third, because fewer conflicts mean that lateral pressure accumulates more. A simulation with a reduction of the resource intensity of the economy to the European levels lowers international conflicts by about one third. The result is meagre for the same reasons as the simulation of reduced military spending. A simulation path that combines the lower resource use with lower military expenditure reduces international conflicts to somewhat less than half of the base simulation level. A further simulation which eliminates almost half of the military stockpile between 2000 and 2010 leads to hardly any further reduction in conflicts. The modeled version of the USA suggests a certain robustness in model US military involvement abroad, caused by the size of the economy and the large military force. Again, such statements refer only to the dynamics studied here and should be taken as a source of insight on causal feedback rather than as a prediction.

Conclusions and implications

The theoretical and practical investigation—based on the integrated theory and the simulation model—can enhance our understanding of the dynamic relations leading to, and following from, conflict and violence in both conceptual and policy terms.

Conceptual extensions

The paper's first extension is conceptual, namely to add the relationship of master variables to internal tension. The simulations for internal tension, in particular, are a new contribution to the tradition of lateral pressure.

The simulations of internal conflict show that there is a correlation between the conflicts simulated by the model and those seen in the historical record, although it is by no means perfect. From the selection of countries simulated, one can say that high internal tension resulting from the constellation of population, technology, and resources is sufficient to lead to conflict, but a low level is *not sufficient* to avoid it, although the domestic conflict level appears lower in countries with low internal tension change. To test the significance more securely, one would like to include a large number of countries. This can be explored in further work.

The second extension pertains to the dynamics of conflict genesis and resolution, in particular the feedback from conflict to population, technology, and military force. The simulations show the importance of the consequences of conflict feeding back into the factors that cause and perpetuate wars and violence. In fact, there are a number of reinforcing feedback loops that might make it very difficult to halt conflict and violence behaviors rooted in the variables specified in the lateral pressure theory.

The theory, with the extensions contributed by this paper, would indicate that a small, weak country can find itself caught in a reinforcing cycle where significant internal tension—due to a high level of population needs relative to resources and technology—leads to a conflict; and violent conflict in turn reduces economic growth. This again increases the probability of conflict. Thus, conflicts may impede the very developments which, if allowed to persist, would reduce future sources of conflict.

By contrast, the extended theory would indicate that the strong countries examined do not experience such high levels of internal tension. As a consequence, they have very few internal conflicts. However, they generally experience lateral pressure (Choucri and North 1993). High lateral pressure caused by high levels of technology (as in the OECD countries) is correlated with two competing loops, one reinforcing, one balancing: high trade and bargaining from high technology reduces conflict, which allows technology to grow further; but a large military force from high technology increases the probability of conflict, which in turn reduces military force and, in the case of local wars, the level of technology.

Some countries, such as South Africa and the United States, have been involved in somewhat more conflicts than the theory of lateral pressure, as specified in our model, might lead us to expect. Another such country, not simulated, is China. This may be a special effect of regional or global superpower status. In the case of the United States, a simulated increase in the resource intensity of its society relative to that of the other OECD countries (an empirical fact) leads to the historically observed number of conflicts. A 'superpower effect' simulated by a high value of military-force effect also leads to the historically observed number of conflicts.

Once a simulation of a country, such as the USA, produces external conflicts, it is difficult to devise strategies within the model specification that stop conflict. Simulations which are moderately successful in reducing the number of simulated conflicts for that country include: reducing the stockpile of military force by 50% between 2000 and 2010; a 50% reduction of resource intensity to the European levels; a 60% military expenditure reduction. The reasons these are not completely successful at eliminating conflict are to be found in the mass of the military stockpile and in the fact that with a lower level of conflicts, the military stockpile and lateral pressure are not subjected to the drain effected by conflicts and therefore can accumulate for longer periods.

Policy issues

So far, this study has provided some useful insights as to the leverage points in the system of society demands, resources, and conflicts that might lead to a more peaceful future. A number of the simulation path-experiments show that it might be very difficult to stop a cycle of conflicts that is rooted in material imbalances. Indeed, there were no hypothetical paths that we could generate to eliminate the simulated conflicts of Burundi and Rwanda. These are cases with high population density and low levels of technology, both of which have a long momentum that is hard to manage or overcome in fast, simple way.

By the same token, it was also difficult to find leverage points which change simulations of frequent US involvement in external conflicts. In this case, the robustness of conflict is due to the mass of military force and the feedback loops which involve military force.

By contrast, if the theory is correct, there are cases—countries such as Angola, Mozambique and South Africa—where violence appears to be influenced by other factors than the dynamics involving the master variables and the intervening variables. These factors could be political, religious, or other social effects. Potentially, tensions caused by such immaterial factors are molded more easily towards non-violent resolution of conflict. This assumes, of course, that political realities and constraints can adjust more rapidly than the adjustment possibilities embedded in the material basis of societies. The historical record is not always encouraging in this respect.

Thus far, this paper has contributed a number of insights into the dynamics and feedback that are inherent in the theory of lateral pressure. Also, empirical validation of the theory was found for a number of countries that were simulated.

We perceive a number of areas for further work. One could calibrate the model to a greater number of countries, to enhance the statistical robustness, so that the preliminary findings of this study could be tested as hypotheses. For example: we would like to test the preliminary result that pressure generated by the master variables is a *sufficient* cause of internal conflict, but a lack of such pressure is *not sufficient* to avoid it.

Also, extension of the model along a number of different directions is desirable. One useful direction to explore further is whether a more complex variable for natural resources improves the historical fit of the model calibrations. For example, one could test resources as measured by: arable land; maximum food production; value of mineral wealth or natural beauty (tourism); or a complex variable composed of these elements. Similarly, the resource intensity of the economy is identified as one possible modification to the simple average wealth per capita variable used in the simulations above. Also, the initialization of lateral pressure and internal tension is problematic because these pressures are specified as the accumulation of many years. It would, therefore, be preferable to use master variable and intermediate variable data that reach back to at least a few decades before the calibration starts.

On the structure side, one could explore the effects of a more integrated formulation of population and economic growth, rather than the exogenous growth specifications used here. This additional piece of work requires a more 'in-depth and broadly structured study of the empirical situation of the countries that are selected to model.

Third, the model could be used to explore more 'political' factors in the genesis of conflict, by introducing structures of power and dissidence, such as modeled by Saeed (1994).

Fourth, at present, each model simulation is for an individual country in an isolated world. This is not the reality for any nation. An interesting study, perhaps related to three above, would include multiple nations, for example, following North's ideas on a hierarchy of nations, and the rise and fall of empires.

While these suggestions point out that there is much work to be done beyond the formulations discussed in this paper, we still would like to emphasize that there are insights to be gained at every stage of model-building. In this paper, these include a number of valuable preliminary results, such as the finding about the sufficiency of master variable constellations for conflict and the apparent robustness of conflicts that are rooted in the master variables.

Appendix: model equations (Vensim)

Master variables

initial population (population) = *user defined*
intrinsic pgr[1] (1/year) = *user defined*
population growth rate (population/year) = (intrinsic pgr * population)/ (1 + impact of conflict)
population (population) = INTEG (population growth rate, initial population)
pop unit (population) = 1
pop impact (dmnl) = population/pop unit
initial technology (technology) = *user defined*
intrinsic tgr[2] (1/year) = *user defined*
technology growth rate (technology/year) = (intrinsic tgr * technology)/ (1 + impact of conflict)

technology (technology) = INTEG (technology growth rate, initial technology)
tech unit (technology) = 1
tech impact (dmnl) = technology/tech unit
initial resources (resource) = *user defined*
resources (resource) = initial resources
res unit (resource) = 1
res impact (dmnl) = resources/res impact

Lateral pressure

lp initial (pressure) = 1
lateral pressure change (pressure/year) = sqrt(pop impact) * sqrt(tech impact)/ sqrt(res impact) * pressure unit
lateral pressure (pressure) = INTEG(lateral pressure change − lp drain, 1)
stress adaptation time (year) = 25
adaptation (pressure/year) = lateral pressure/stress adaptation time
lp drain (pressure/year) = (adaptation + 0.5 * International Conflict/year)
lateral conflict break point (dmnl) = 40
pressure unit (pressure) = pressure/year

Internal tension

ip initial (pressure) = *user defined*
internal tension change (pressure/year) = sqrt(pop impact)/(sqrt(tech impact) * sqrt(res impact)) * pressure unit
internal tension (pressure) = INTEG(internal tension change − ip drain, ip initial)
ip adaptation time (year) = 25
ip adaptation (pressure/year) = internal tension/ip adaptation time
ip drain (pressure/year) = (ip adaptation + 0.5 * Domestic Conflict/year)

Military

cost of arms (arms) = 1
Initial MF(arms) = initial technology * initial population * cost of arms
mf spending propensity (1/year) = *user defined*
Military Expenditure (arms/year) = GNP * mf spending propensity * cost of arms
military force (arms) = INTEG(Military Expenditure − mf drain, initial MF)
Mf Depreciation Rate (1/year) = 0.05
Mf depreciation (arms/year) = military force * Mf Depreciation Rate

Costs per Conflict per year (arms/year) = 0.4 * military force/year
Annual Military Costs (arms/year) = Costs per Conflict Year
* International Conflict/pressure
armsout f(dmnl) ([(0, 0)-(2, 1)], (0, 0), (0.1, 0.1), (0.25, 0.5), (0.5, 0.9), (1, 1), (2,1))
armsout effect (dmnl) = armsout f (military force/Initial MF)
military force effect (dmnl) = sqrt(military force/arms)
arms (arms) = 1
mf drain (arms/year) = armsout effect * (MF depreciation
+ Annual Military Costs)

Trade and bargaining

TBL multiplier (dmnl) = 1
trade and bargain leverage (dmnl) = sqrt(technology) * TBL multiplier

International conflict

lateral conflict break point (dmnl) = 40
P of Int'l Conflict (pressure) = DELAY FIXED((lateral pressure * military force effect/trade and bargain leverage) + International Conflict)/lateral conflict break point, 1, 0)
International Conflict (pressure) = IF THEN ELSE (P of Int'l Conflict > 1, 1, 0)

Domestic conflict

internal conflict break point (dmnl) = 5
P of Domestic Conflict (pressure) = DELAY FIXED (internal tension + Domestic Conflict)/internal conflict break point, 1, ip initial)
Domestic Conflict (pressure) = IF THEN ELSE (P of Domestic Conflict > 1, 1, 0)

Impact of conflict

intensity of conflict (dmnl) = 0.005 * military force/initial MF
impact of conflict (dmnl) = (intensity of conflict * (International Conflict
+ Domestic Conflict))/pressure.

Notes

1. intrinsic pgr = intrinsic population growth rate, which applies in the absence of conflict.
2. intrinsic tgr = intrinsic technology growth rate, which applies in the absence of conflict.

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