World-Size Global Markets Lead to Economic Instability

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Abstract Economic and cultural globalization is one of the most important processes humankind has been undergoing lately. This process is assumed to be leading the world into a wealthy society with a better life. However, the current trend of globalization is not unprecedented in human history, and has had some severe consequences in the past. By applying a quantitative analysis through a microscopic representation we show that globalization, besides being unfair (with respect to wealth distribution), is also unstable and potentially dangerous as one event may lead to a collapse of the system. It is proposed that the optimal solution in controlling the unwanted aspects and enhancing the advantageous ones lies in limiting competition to large subregions, rather than making it worldwide.

Keywords
Globalization, competition, reaction-diffusion, Monte Carlo simulation, Lotka-Volterra

1 Introduction

Economic and cultural globalization is one of the most important processes humankind has been undergoing lately. This process has had important advantages in the past, such as the rise in the quality of life in all the western countries and some of the eastern ones, and the widespread availability of physical and spiritual goods. However, globalization has attracted many enemies. The main claim against it is that it leads to accumulation of wealth within a small part of the world, to the destruction of diversity, and to weak economies in the rest of the world.

In face of the debate regarding globalization, it is desirable to confront the problems from an objective point of view. We present here the results of a quantitative analysis of the effects of globalization based on a microscopic representation in a model that has already been used successfully to characterize the emergence, resilience, and sustainability of social, ecological, and financial systems [1]. This model describes the economy in terms of very simple interacting agents distributed in space. It represents the motion, generation, and consumption of resources, economic entities, and capital. In this quantitative model, globalization is characterized primarily by increasing the distance range R over which competition between economic agents, companies, or capital can take place. The dependence of the wealth dynamics on the competition distance R will be the focus of our quantitative study. The main factors limiting the distance R and therefore globalization in the real world are:

- Customs and regulations (for example, the Concorde cannot compete within the USA because of air traffic regulations; this limits its globalization radius R to Europe).

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- Technical incompatibilities (for example, US electric appliances do not fit the European power network, so their competitivity is hindered outside North America).

A complementary concept to globalization, which crucially affects the dynamics of the system, is wealth redistribution. In our model, this is represented quantitatively by the probability rate D for a unit of capital or an agent to move from one location to a neighboring one. The parameter D is called the *diffusion coefficient.* Spreading the wealth uniformly over the entire planet (infinite D) might look noble. However, according to our model, this would lead to complete vanishing of the wealth. We argue that extreme values for globalization R and redistribution D (as advocated respectively by extreme capitalism and extreme socialism) are equally counterproductive and possibly disastrous. However, reasonably finite D and R values are beneficial. In particular, maintaining somewhat decoupled regional economies is less than efficient during good economic periods, but turns out to be helpful in avoiding worldwide irreversible collapse in bad times.

To study these issues quantitatively, we modified a previous model [1] to include market globalization and varied the distance (R) between companies that compete.

2 Motivation and History

The new economy and globalization are a new phenomenon, and predictions regarding their future are partly based on extrapolations from the current trends. However, the current trend of globalization is not unprecedented in human history. History reveals that the equivalent of globalization in closed societies, isolated within observable boundaries, has indeed occurred frequently. Each time, local economies (such as farms, families, and groups of hunters and gatherers) discovered some superior form of organization or method, and a movement toward "mini-globalization" occurred. Consequently a large dominating organization was established in each such process, which ruled the entire world that was known to those groups at the time.

Just as today, globalization involved primarily the method or trade and the range of influence. Secondarily, globalization affected other functional characteristics: the social distribution of profits, the places where people decided to live, and so on. Paradoxically, the consequence of globalization was localization in so far as these financial, social, political, and demographic effects were concerned. Consequently, while the superior organization was strong compared with the environment under its dominion, it was left in certain respects vulnerable to unexpected threats, which led eventually to a sudden collapse of the entire civilization. Let us illustrate this pattern with a few examples.

For about a thousand years, the Maya people ruled what is today a large part of Mexico and southern Central America. They built huge cities and enormous monuments. Then, suddenly the Mayan Empire collapsed, leaving thousands of elegant stone carvings to be covered by the tropical forest. The Mayan civilization vanished after a very noticeable process of globalization of their economy, which relied on sophisticated techniques to grow and exploit corn.

Consider another example: Around 3500 B.C. communities moved from the west side of the Indus to the east. Permanent settlements began to rise, depending entirely on the Indus River system. This civilization lasted from about 2500 B.C. to 1500 B.C., followed by an abrupt unexplained end. Some of the proposed explanations involve local accumulation of profits and people together with globalization of methods, products, and techniques.

A similar process took place in ancient Mesopotamia about 4000 years ago. One well-studied example is the city Mashkan-shapir.

These examples of ancient globalization processes may help us to gauge our generic model and to analyze quantitatively the prospects for the present and future of our own civilization. The historical cases ended with a sudden and total collapse, by a factor of about 100, of the economy and of the population size. Can history serve as a warning?

3 Formulation of the Dynamical Model

The roots of the model of economic growth can be traced back to the economist and demographer Thomas Robert Malthus [4, 5], who wrote in 1798 the first equation describing the dynamics of autocatalytically proliferating individuals:

$$\frac{dN}{dt} = (birth - death)N \tag{1}$$

where N is the cumulative number of individuals of the species $\boldsymbol{n}$, and *birth* and *death* are the natural birth and death rates. Its exponential solution was found to fit real-life growth in various biological cases:

$$N(t) = N(0)\exp[(birth - death)t] \tag{2}$$

For the values *birth* and *death* of humans at the time of Malthus this solution predicted a growth to infinity by doubling of the population every 30 years (of course, for $birth < death$ the population would decay exponentially). The exponential population rise (or decrease) is due to the feedback of the population size on itself. A large population grows faster than a small one.

A correction to Malthus' equation, offered by P. F. Verhuulst [6] in 1838, ensured a more realistic growth pattern with saturation terms:

$$\frac{dN}{dt} = (birth - death)N - compete\, N^2 \tag{3}$$

The coefficient *compete* represents the competition of the individuals for resources, in that the probability that two $\boldsymbol{n}$ individuals are trying to access a resource independently equals the square of the probability that one $\boldsymbol{n}$ is trying to access that resource. Since the probability that one of the N individuals of type $\boldsymbol{n}$ tries to access the resource is proportional to N, the competition term is proportional to N^2.

In the economic context, the Verhuulst equation can be written as $dN/dt = (gain - loss)N - compete\, N^2$, where N is the capital and *gain* and *loss* are the average gain and loss percentages on the capital.

The solution, the logistic curve, is seen in Figure 1. This S-shaped curve captures adequately the fundamental behavior of many processes of growth and propagation:

- For $gain - loss < 0$, the capital decays to 0 exponentially.
- For $gain - loss > 0$, at the beginning the capital increases exponentially, but eventually the growth slows down, so that it never reaches the maximal asymptotic value.

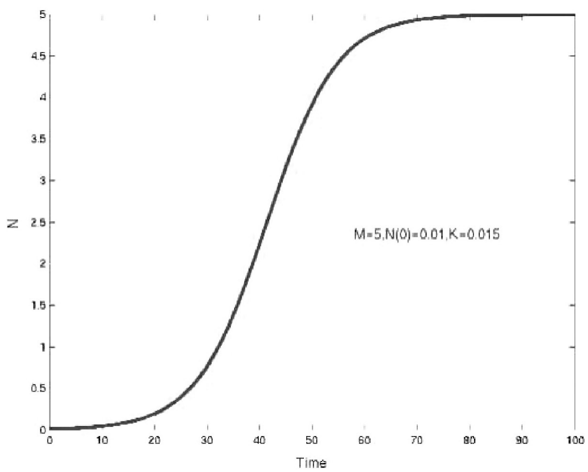

Figure 1. An S-shaped solution of the logistic Equation 3 for *birth* − *death* > 0. The curve starts with an exponential increase and then saturates at the carrying capacity *N* = (*birth* − *death*)/ *compete*.

Over the years Verhuulst's logistic curve (Figure 1) has been used in a very wide range of growth models in the social sciences [7–9]. For example, in thousands of papers (as reported by Rogers [10]) the diffusion of innovation as a fundamental aspect of growth in economically based society has been studied, yielding a variety of models.

The Verhuulst logistic equation was extended to a similar formalism by Lotka [11] and Voltera [12] to represent populations of predators and prey. Let us consider the situation in which each individual of the species $\boldsymbol{n}$ may multiply (with a certain probability rate per unit time λ) only in the presence at its location of food in the form of an individual from another species $\boldsymbol{a}$. The growth rate is then given by $\lambda A - death$, and therefore Equation 3 becomes

$$\frac{dN}{dt} = (\lambda A - death)N - compete\, N^2 \quad (4)$$

where A is the number of individuals of the species $\boldsymbol{a}$. In the framework of an economic model, N represents the number of investors or the capital, while λA represents the capital growth potential depending on the abundance A of profit opportunities $\boldsymbol{a}$. We would thus rewrite Equation 4 as $\frac{dN}{dt} = (\lambda A - loss)N - compete\, N^2$, where N will again be the total capital.

For constant A such that $\lambda A - loss < 0$, starting from a finite capital $N(0)$ leads eventually to an exponential decay:

$$N(t) \approx \exp[(\lambda A - loss)t] \to 0 \quad (5)$$

For $\lambda A - loss > 0$, starting from a small value of N leads initially to an exponential increase and then to saturation at the value

$$N \approx \frac{\lambda A - loss}{compete} \quad (6)$$

The logistic Lotka-Volterra system was extended to include spatially extended populations. One way to represent it is to imagine an m-dimensional grid with a number of individuals $N(x, t)$ placed at each node x of the grid. The ***a*** and ***n*** individuals can jump (diffuse) randomly with some probability D to neighboring sites. In the economic context, movement of ***n*** would represent a transfer of capital, while movement of ***a*** would represent movement of gain opportunities.

The effect of the diffusion of the ***n***'s between neighboring sites is represented *on average* by a term denoted as Laplacian $N(x, t)$ in the honor of the physicist and mathematician Pierre-Simon Laplace (1749–1827); see the appendix for details. The Laplacian term has the effect of spatially homogenizing the capital $N(x, t)$ and thereby eventually smoothing any spatial perturbations. Once the capital is homogeneous, the diffusion term Laplacian $N(x, t)$ becomes 0. On including the average effect of the diffusion in the Lotka-Volterra Equation 4, the *average* time variation of $N(x, t)$ becomes

$$\frac{dN(x, t)}{dt} = [\lambda A(x, t) - loss]N - compete\, N^2 + D \text{ Laplacian } N(x, t) \tag{7}$$

In the homogeneous case, when Laplacian $N(x, t) = 0$, Equation 7 reduces to Equation 4.

We will see now that considering the average time variation $dN(x, t)/dt$ and assuming that the system can be described in terms of smooth spatial functions $N(x, t)$ and $A(x, t)$ may lead to dramatically erroneous results. Indeed, assuming that the ***a*** population can be described by the local average $A(x, t)$ implies that the diffusion of the individuals of ***a*** can be expressed by the equation

$$\frac{dA(x, t)}{dt} = D \text{ Laplacian } A(x, t) \tag{8}$$

and therefore A approaches after some time a spatially homogeneous value A_0. Since the number of ***a***'s is conserved, the value A_0 depends only on the initial number of ***a***'s. In the case in which the *a*'s can disappear (die, be consumed, be removed) with a certain probability rate *fade* and appear with a probability rate *appear*, Equation 8 becomes

$$\frac{dA(x, t)}{dt} = D \text{ Laplacian } A(x, t) + appear - fade\, A(x, t) \tag{9}$$

which leads to a steady uniform ***a*** population

$$A_0 = \frac{appear}{fade} \tag{10}$$

Assuming now that this number is such that $\lambda A_0 - loss < 0$ [in all the runs reported here this condition is fulfilled: $appear = 0.0025$, $fade = 0.01$, $A_0 = 0.0025/0.01 = 0.25$, $\lambda = 0.4$, $loss = 0.2$, $\lambda A_0 - loss = 0.1 - 0.2 = -0.1 < 0$] and taking into account the homogenizing influence of D Laplacian $N(x, t)$, Equation 7 reduces to Equation 4, and the capital $N(x, t)$ decays to 0 according to Equation 5. This would mean that in a very wide range of conditions, economy, civilization, and life would be impossible. In particular, in conditions in which the capital, investment opportunities, and the like could be represented by continuum functions (ignoring their discrete composition), the dynamics would lead to a uniform distribution, which in the end would destroy any possibility of sustaining an economy.

Fortunately the continuum argument is fallacious. In reality local fluctuations emerging (among other reasons) from the discrete character of the $\boldsymbol{a}$ and $\boldsymbol{n}$ individuals imply that microscopically, the number of $\boldsymbol{a}$ particles on each site is never exactly uniform. In fact, even if the probability for every particle $\boldsymbol{a}$ to be on any site is rigorously uniform, there is a finite probability of having at some moment an arbitrarily large number $A(x, t)$ of $\boldsymbol{a}$'s on a site x. In particular, on such a site one may have $\lambda A(x, t) - loss > 0$, which leads to an *increase* of the capital $N(x, t)$ on that site.

If this situation persists long enough on site x, the capital $N(x, t)$ on this site and in its neighborhood will increase exponentially according to Equation 5. Thus, the microscopic stochastic fluctuations of the $\boldsymbol{a}$ population are amplified by the dynamics (Equation 7) macroscopic features in the $\boldsymbol{n}$ population. Of course, Equation 8 ensures that any fluctuation in the local $\boldsymbol{a}$ population will eventually evolve and be displaced, but new configurations will always present fluctuations intrinsic in the discrete character of the $\boldsymbol{a}$'s. In fact, the regions of large $N(x, t)$ will change their location following the fluctuations in $A(x, t)$.

Consequently, instead of a uniform capital density $N(x, t)$, one will observe islands of large N moving in a sea of $N = 0$. The islands have adaptive behavior: they search and exploit the advantageous A fluctuations. This is an emergent property: the individuals of $\boldsymbol{n}$ move totally randomly, die, and are born; they do not follow the A motion. Therefore the $\boldsymbol{n}$ capital is saved by the emergent properties of the collective $\boldsymbol{n}$ islands, in spite of the fact that a treatment based on a continuous function describing the A and N densities would predict extinction of $\boldsymbol{n}$.

The discrete and autocatalytic characters of life and of the economy conspire in optimizing, by an "invisible hand" at the collective level, even systems that in the continuum approximation would not have any chance of survival in view of their poor efficiency or adaptability. This happens by the spontaneous selection of limited subsets for survival: the current optimal restricted regions ensure the sustainable survival of the system even in naively hopeless conditions.

This model provides a dynamical realization of Adam Smith's idea that the selfish capitalist reproduction of the $\boldsymbol{n}$'s leads naturally to generic market efficiency. This happens at the price of the emergence of large inhomogeneities in the spatial or social distribution of wealth $N(x, t)$, reflecting the underlying stochastic distribution of growth or gain opportunities $A(x, t)$. Any attempt to correct this inequality by uniformizing the system (say with a large diffusion coefficient D) results in the disappearance of the entire capital. The model therefore describes quite faithfully the fallacy of the various communist proposals: a uniform distribution of wealth would disable the above intrinsic capability of the discrete autocatalytic systems to generate, search for, and exploit space-time-localized growth or profit opportunities. The model above has been applied and validated in a wide range of financial, social, biological, and ecological systems [13–16].

Numerical simulations confirm the theoretical analysis: Wealth that is accumulated at some point will diffuse to neighboring regions and will lead to a distribution of wealth that is fluctuating in space (Figure 2). The distribution of N will consist of many islands with relatively large wealth scattered across a very poor background.

The distance over which the wealth is distributed (island sizes) depends on the diffusion rate D. The local competition and the macroscopically homogeneous distribution of the $\boldsymbol{a}$'s implies that in spite of the inhomogeneity that the system displays at the scale of the typical island, the system becomes homogenous at scales much larger than the island size. This induces a relatively uniform distribution of wealth on the global scale. The local changes in the distribution of $\boldsymbol{a}$'s may lead to the displacement or even disappearance of certain islands, but since there are many islands, the overall level of

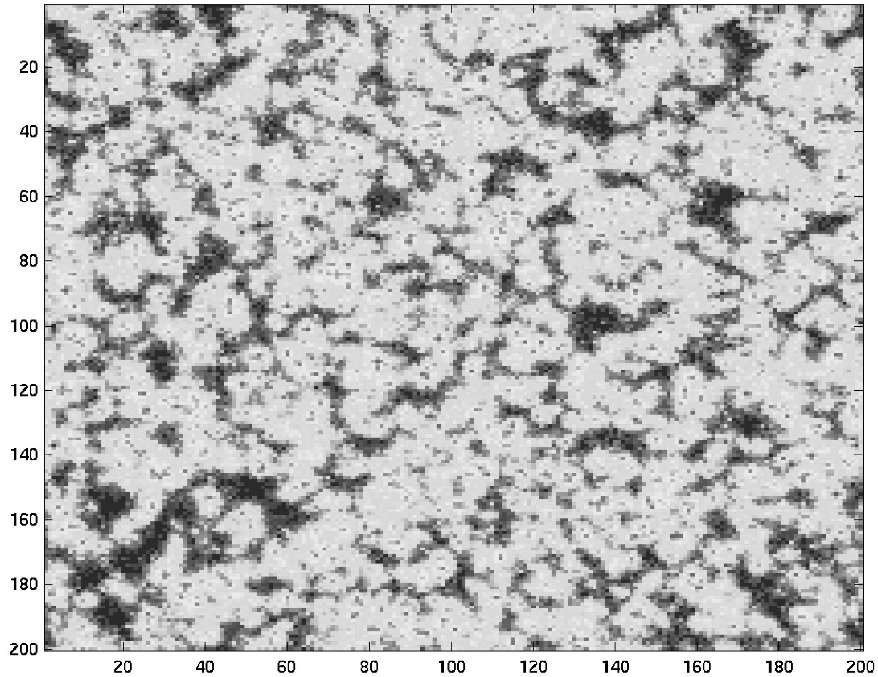

Figure 2. The typical spatial distribution of wealth for globalization radius $R = 0$ (that is, only individuals of ***n*** placed on the same grid point compete). Note the irregularly scattered active islands of maximal wealth. The color scale is logarithmic, so the islands are significantly higher than the background. They display adaptive behavior: move, join, split, shrink, and expand. The size of the lattice was 200 × 200. The other parameters were chosen as mentioned in the main text to ensure $A_0 = 0.0025/0.01 = 0.25$ and $\lambda A_0 - death = -0.1 < 0$. Thus, according to the naive continuum approximation, the distribution would be expected to be uniformly 0.

N in the system has relatively small random fluctuations around a fixed sustainable value (smooth lower curve in Figure 3). Even if a small island disappears, the influence of this event will be averaged out in the total capital by the random variations of the other islands. The system is globally very stable.

4 Applying the Model to Globalization

We will see that in the presence of globalization this picture is significantly affected. The main features that we will find are:

- Globalization of competition over the entire system leads to localization of wealth $N(x, t)$ and to
- Catastrophic fluctuations in the total ***n*** population.
- Even averaging over the fluctuations, the average total wealth is not optimal for extreme globalization.
- There is a regional globalization scale that optimizes the system.

Let us suppose that the competition between the various individuals or companies is not limited to neighbors residing on the same site $[-compete\, N(x, t)^2]$, but extends to all the individuals residing within a radius R from each individual. More precisely, the

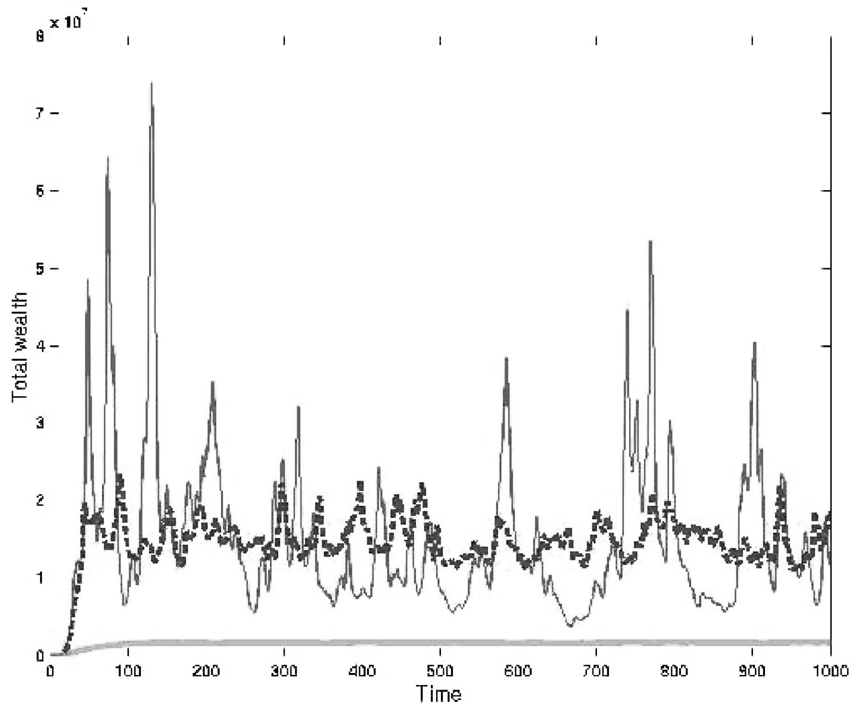

Figure 3. The time evolution of the total wealth for $R = 0$ (bottom smooth solid line), $R = \infty$ (spiky solid line), and intermediate R (dashed line). All the other parameters are as in the caption of Figure 2. Note that the intermediate competition case $R = 40$ (dashed line) ensures the maximal average. Note also that the totally globalized case (R = system size = 200) is better even at the worst moments than the completely localized market case ($R = 0$). However, the dramatic crashes involve of course massive human suffering (loss). This is avoided for $R = 40$.

presence of an individual $\boldsymbol{n}$ at site x induces the death probability rate *compete* $/R^2$ for any $\boldsymbol{n}$ placed on any site y such that $|y - x| < R$ [in the continuum approximation this would be represented by a term $-compete\, N(x, t)$ Average $N(y, t)$].

Our model shows, in agreement with the actual facts, that the globalization of competition does not lead to a globalization of the wealth distribution. Indeed, the presence of an island with large capital $N(y, t)$ around some site y will inhibit the appearance and survival of other islands within a radius R around that location. Therefore, replacing the local competition ($R = 0$) with competition over a larger scale ($R > 0$) leads directly to a more localized distribution of wealth (Figure 4).

The distance between the islands is of the order of the competition distance (R). This corresponds to the existence of one main center for any region of size R that underwent globalization. (Similarly, localization can take place in the abstract ownership space, as in the case of food, retail, or motel businesses being taken over by national chains.)

This regional globalization results in an increase of the wealth within each region and in the world, since it helps the concentration of capital at the optimal current location within the radius R (rather than wasting capital in less optimal locations). One sees in Figure 3 that in the regional globalized case, $\infty > R > 0$ (dashed line), the wealth is systematically larger than in the $R = 0$ case (smooth bottom solid line). One also sees in Figure 5 that the average of the capital over time increases with the competition distance R (except for very large R values, which we will discuss later). The total wealth in the process of globalization increases by a very large factor with no change of the A distribution. Thus the regional globalization of the economy leads to a very

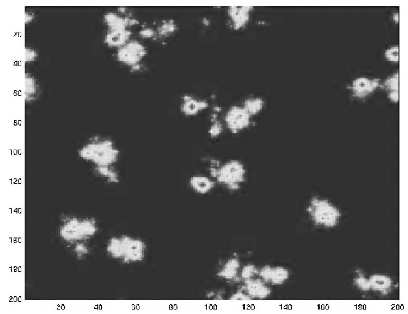

Figure 4. The spatial distribution of active wealth islands in the regional globalization regime $R = 40 <$ (system size) $= 200$. The snapshot was taken after 1000 steps (long after the system equilibrated). One sees that the islands are larger and sparser than in the $R = 0$ case. In fact, the average distance is, as expected, roughly equal to $R = 40$.

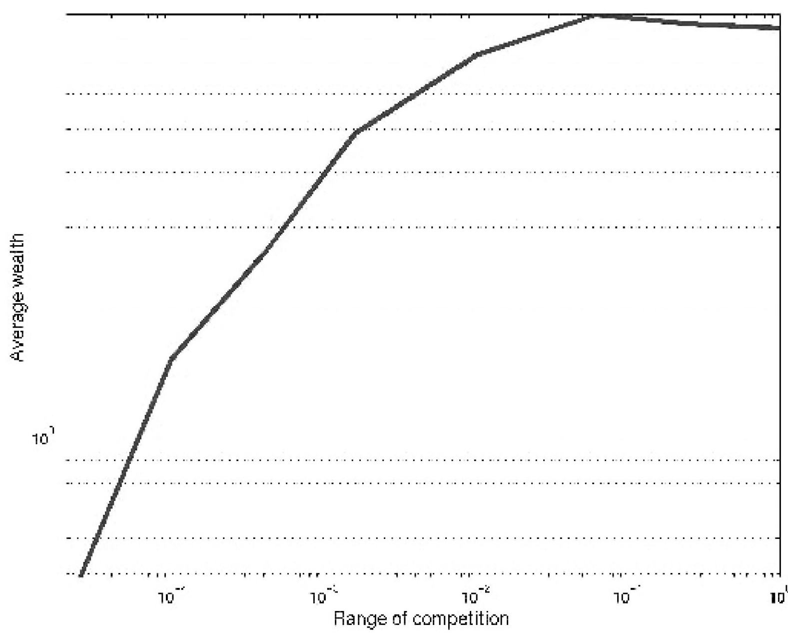

Figure 5. The time average of total wealth as a function of the globalization radius (measured in units of the system linear size). The globalization radius is defined as the scale of competition between *B* agents. A competition radius of zero is equivalent to local competition; the maximal competition radius presented in the drawing represents a competition over the entire lattice size (a numerical value of one). The scale is doubly logarithmic. One sees that wealth increases with globalization radius *R* except when *R* becomes of the order of the system size itself. The optimal *R* is at a value about 1/10 of the system size.

localized (some would say unfair) distribution of wealth, but to an impressive rise in the total wealth since the entire capital is localized at the locations with the current optimal growth potential within each region.

The price paid is in more significant system fluctuations. If the competition distance *R* is of the order of the system size, there will be only a small number of islands, and the system fluctuations related to their appearance and disappearance will be more significant. Yet, the disruption created by the disappearance or dramatic shrinking of one island will be readily compensated by the neighboring regions taking over (or, depending on your political interpretation, sending capital to) the affected region.

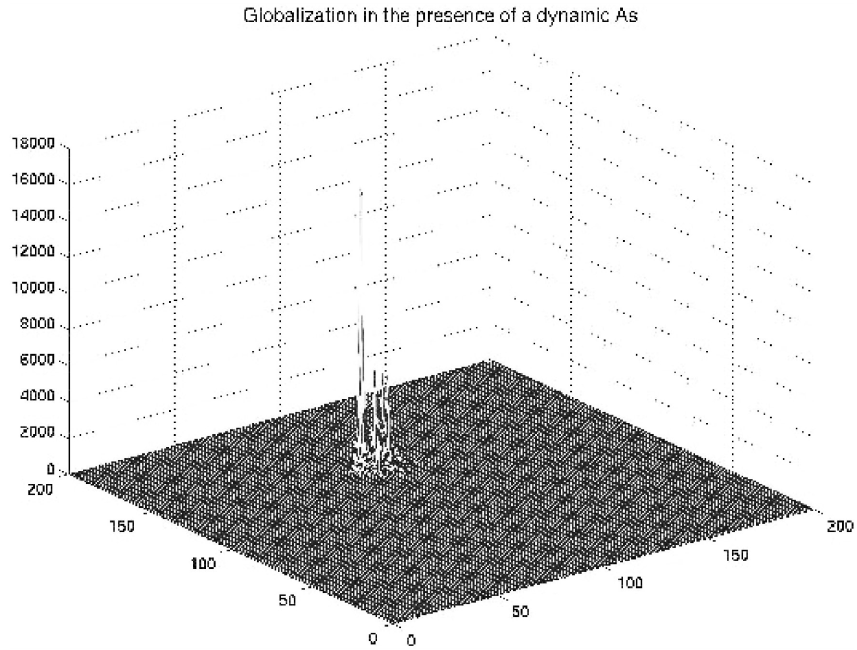

Figure 6. The wealth spatial distribution for R = system size = 200 (every $\boldsymbol{n}$ competes with every other $\boldsymbol{n}$ irrespective of distance). Only one active wealth island survives.

Let us now see what happens in the limit in which the competition distance R is as large as the entire system (planet). Then all the wealth is completely localized in a single N island (Figure 6). Such globalization can lead to a grim future. In contrast with the distributed economy (small R), which was insensitive to the stochastic fluctuations of the A configuration, the localized state is very sensitive to the fluctuation in A: if the conditions change and life becomes impossible at the location of the current island, the wealth within the island will collapse. Since this is the entire system capital, its loss will be felt dramatically in the global count (Figure 3, spiky line). To make things worse, whereas in the presence of additional islands the recovery would be smooth and immediate because the other islands would be expanding within the territory vacated by the disappearance of the collapsed one, in the case of extreme globalization the collapse of the unique island will leave a long-lived vacuum, since there are no $\boldsymbol{n}$ seeds for recovery at the locations that could constitute alternative centers (due to a reasonably favorable $\boldsymbol{a}$ configuration there). Therefore the system will present very severe violent collapses (Figure 3) followed by long periods of desolation. As a consequence, even after time averaging, the performance of the totally globalized system is worse (Figure 5) than that of the regionally globalized one (but better than the local market economy, $R = 0$).

To summarize, we have obtained using our computer simulation methods the following results:

- For small competition range $R \approx 0$, the wealth production concentrates spontaneously in islands of activity which are densely and uniformly distributed across the system (Figure 2). These islands follow adaptively the locations of high growth potential that the random external circumstances generate in their neighborhood. Attempts to induce further uniformization of wealth by imposing intensive wealth redistribution ($D \to \infty$) lead to the disappearance of the active islands. In turn this causes the collapse of the wealth in the entire system, because the capital ends up typically at locations with negative growth potential.

- By increasing the competition range to $R > 0$, the islands that are closer to each other than the distance R are forced to compete. Consequently, only one wealth island can survive within each region of size R (Figure 4). This makes the system more efficient than the $R \approx 0$ case (Figures 3 and 5), because the wealth is forced (guided) to concentrate at the location of highest gain (growth) potential in the entire neighborhood (up to distance R). When the conditions at the location of a given wealth island change for the worse due to unfortunate stochastic circumstances, the island migrates (if the change in the conditions is slow enough to allow adaptation) or disappears. However, the wealth on the vacated territory is regenerated quickly by diffusion of capital (D) from the neighboring islands once the negative conditions disappear.
- In the limit in which the competition distance R is of the order of the system size ($R \to \infty$), there is only one wealth island left (Figure 6). As long as the island is located at the current optimal growth spot, the total wealth of the system grows along a very efficient path. However, once the conditions at the location of the island become suboptimal, the island collapses and with it the total wealth in the system (Figure 3). The recovery is very slow, since there is no capital left in the system to restart growth at the new optimal location. On average the total globalization case ($R \to \infty$) is less efficient (Figure 5) than the moderate regional localization case ($0 < R < \infty$).

Therefore, moderate-size [$R \approx$ (size of the entire system)/10] regional markets, partially protected from external competition, are the optimal economic configuration. This type of market has a large enough level of competition to lead to the rise in the total wealth by ensuring that the capital is placed at the optimal growth location of every R-size region. On the other hand, the distribution of the wealth in several disjoint submarkets protects each region from "catching" the crises affecting its neighbors. The protection of regional economies (Europe, North America, Asia, etc.) from all-out external competition by limiting globalization (through maintaining various trade, technological-compatibility, and social-cultural barriers) maintains them as independent economic entities. The inefficiency implicit in this is paid back in times of crisis: the eventual collapses related to fortuitous fluctuations in the local conditions will affect only one of the regions at a time. Capital migration between regions allows the ready recovery of the crisis-affected ones by capital transfer from the surviving, unaffected neighboring regions.

- If for instance Argentina goes bankrupt, it will still survive because of wealth diffusion from the US economy, which is still strong. That wouldn't be the case if Argentina were alone on the planet.
- In turn, during hard times, the US economy was helped by the fact that Japan and Germany had separate, independent economies which did not undergo crises at the same time. Likewise, the existence in the world of a relatively independent, unaffected US economy helped the recovery of the Asian markets (as with Germany and the Marshall Plan in the fifties).

In the case of the Nasdaq, the uniformity of the electronic conventions and the impossibility of imposing effective taxation barriers mean that the globalization is worldwide and the recovery from the present collapse might take a long time.

The optimal range of globalization R as well as the optimal rate of wealth redistribution (D) should be based on a detailed quantitative study.

5 Discussion

One could argue that the grim effects of globalization can be changed if the opportunities for fortune accumulation are less rigidly distributed in space, and that this can be achieved by allowing the free movement of money, technologies, know-how, manpower, and production facilities to poorer regions (which would be translated in our model into a high $\boldsymbol{a}$ diffusion). This solution will indeed stop the wealth localization, but by doing so it will stop the main motor driving the modern economy.

In fact, we have seen above that the emergence of localized $\boldsymbol{n}$ islands is the very mechanism through which the $\boldsymbol{n}$ population can survive. The only chance for any region to raise its wealth is through the localization of the production capacities at the locations currently rich in $\boldsymbol{a}$'s. Thus the mechanism leading to the rise and survival of economies on the small scale is the same mechanism that leads to their destruction on a global scale.

A better solution seems to be keeping the competition range limited to large subregions (for example, within North America or the unified Europe), but allowing a reasonable rate of money and technology transfer between regions. These would be translated, in the model, into a regional competition mechanism (medium range R) coupled with a high enough rate of $\boldsymbol{n}$ diffusion (enough to make the islands themselves of order R).

This regime would, on the one hand, enable regional economies to grow and survive the effects of external competition. On the other hand it would allow a transfer of new growth seeds (whether money or technology) to new regions (see Figure 6 and dashed curve in Figure 3). Our simulations show that in the long term the total wealth of society is as high (if not higher) in this regime than in the case of global competition. Moreover, this regime leads to a more uniform distribution of wealth.

In recent years, there have been a lot of applications of emergent collective phenomena in the social sciences [17, 18]. Many crucial complex properties that were believed to depend on unknown human factors and therefore to be difficult to treat in a formal quantitative way have been analyzed through a microscopic representation approach [19–21]. In this article we have demonstrated that there is great resemblance between various systems of growth: biology, social systems, and so on. This consistency is attributed to the fact that all these systems have similar mechanisms that govern the dynamics of their growth. From biology to the economy, from Malthus to Lotka and Volterra, from the Mayas to the new economy, the picture is dominated by similar patterns and principles: as long as the competition for resources is regional, the economy, and life in general, are stable. Global competition, besides being unfair (through allocating wealth among the few strongest competitors), is potentially dangerous, in that a single event may lead to a collapse of the system.

The new economy [22], driven by high technology and globalization, seems to be changing old economic relationships. Could globalization be undone? Not so easily, because it goes much deeper today than ever. Many more economies are now part of the global market, and economies and multinationals are much more interconnected.

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Appendix

The expression for and properties of the Laplacian are briefly obtained as follows.

Each of the $N(x, t)$ individuals situated at time t on site x is allowed to jump (diffuse) randomly to each of the $2m$ neighboring sites with a probability rate per unit time $D/2m$.

Consequently, out of the $N(x, t)$ individuals at site x, an average of $TN(x, t)D/2m$ will jump to each of the neighboring sites during the time interval t to $t + T$. Reciprocally, an average of$TN(y, t)D/2m$ individuals will jump to x from any of its neighbors y. Consequently, the average variation of the population per unit time,

$$\frac{dN}{dt} = \frac{N(x, t + T) - N(x, t)]}{T}$$

at the site x between time t and time $t + T$, is the difference between the population flows to and from site x from its neighbors:

$$N(\text{neighbor 1 of } x)\frac{D}{2m} + N(\text{neighbor 2 of } x)\frac{D}{2m} + \cdots + N(\text{neighbor } 2m \text{ of } x)]\frac{D}{2m}$$
$$= D \times (\text{average population of the neighbors of } x)$$

The population flow emigrating from site x toward its $2m$ neighbors is $DN(x)$. The operation of taking the difference between the average of N over the neighbors of x and the value of $N(x, t)$ is symbolized by Laplacian $N(x, t)$. With this convention, the average variation per unit time of the population $N(x, t)$ due to diffusion is D Laplacian $N(x, t)$. Note that if $N(x, t)$ is larger (smaller) than the average of its neighbors, Laplacian $N(x, t)$ is negative (positive).