The Puzzle of the Diffusion of Central Bank Independence Reforms: Insights from an Agent-based Simulation

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Abstract

The emergence of an ever-widening sphere of global public policy is a new reality in a world characterized by the blurring of boundaries between the national and the global; by flows of ideas, people and commodities; and by new global risks and opportunities. In this context, this paper explores the empirical puzzle of the sudden outbreak of reforms leading to central bank independence. How can we best understand the outbreak of reforms in the 1990s? It is suggested here that the reforms were diffused in a contagious and an uncoordinated manner in a global policy process that may best be captured by Kingdon's policy stream model. We develop an agent-based model to evaluate the effects of three relatively unexplored aspects of the diffusion process. These are (1) the likelihood of the outbreak of reform; (2) the rate of adoption of the reform; and (3) the time to outbreak. We find that the likelihood of outbreak depends on the saliency of a problem, in conjunction with the length of time that a problem has been on the public agenda. We also find that an increase in the size of the environment surveyed before making a decision increases the rate of adoption but also the time to outbreak. The more global the information available for our agents, the longer is the time to outbreak, but outbreaks unfold much faster.

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This paper explores the changing patterns of policymaking in an increasingly interconnected world. Interconnectivity, which stimulates an ever-growing flow of readily accessible information on all aspects of life, facilitates the spread of ideas, administrative reforms and the movement of individuals, making it faster and cheaper then ever before (Rosenau 2007). This process constitutes a global interconnected environment in which the propensity to adopt new ideas and practices is positively correlated with the adoption of the same or similar ideas by others. In the realm of policy analysis, the contagious diffusion and uncoordinated adoption of policy innovations are now more effective than ever before, and shape trends towards global public policymaking. They are constitutive elements of an emerging sphere of global public policy, in which actions, events, problems and solutions in one part of the globe are increasingly visible, significant and influential elsewhere (Reinicke 1998).

To help us understand the changing character of policymaking in a global sphere, this paper examines the sudden outbreak of the popularity of reforms leading to central bank independence in the 1990s. Why did so many governments start frantically to delegate authority to their central banks during the 1990s, granting them more legal, formal and most often also practical autonomy from elected officials? While the autonomy of central bankers was always valued in the financial community (Goodhart 1988; Capie et al. 1994), only nine countries increased the autonomy of their central banks in the 1970s and 1980s. In the 1990s, however, enhanced autonomy of central banks (as well as other professional regulators) became a major feature of institutional reforms that spread all over the world (Levi-Faur, 2005). No fewer than 84 countries increased the formal autonomy of their central banks from 1990s to 2008 – a sharp and sudden increase in the rate of adoption of central bank independence starting in 1989 (see Figure 1).

[Figure 1 about here]

The literature on central bank administrative reforms offers a wealth of explanations and debates that are rooted in different levels of analysis and grounded in different paradigms of political and economic change. The core debates cluster around three central divides: functionalist versus power-centered approaches; materialist

versus constructivist approaches; and state-centric explanations versus explanations emphasizing the centrality of the international arena (Rogoff 1985; Cukierman 1994; 1996; Bernhard 1998; Goodman 1991; McNamara 2002; Jayasuriya 2001; King 2005; Simmons 1996). So far, in spite of recognizing the importance of policy packages drawn from major players in the international system on a state's policy choice and institutional design, scholars have refrained from formally modeling such experience as a causal mechanism for the global outbreak of central banks reform (for a notable exception, see Polillo and Guillén 2005). Most of the literature avoids adopting a diffusion perspective in explaining the sudden outbreak and rapid global spread of central bank autonomy reform.

Intrigued by the global spread of the reforms, this paper introduces a theoretical framework explicitly designed to study policy diffusion in a global context. The theoretical framework rests on John Kingdon's policy streams model (1995 [1984]) and more generally on the garbage can model of policymaking that originally informed it (Cohen et al. 1972). We offer a formal description of the theoretical framework, develop an agent-based model and use computer-assisted simulation to study the interactions between the various components of the model. This allows us to model and study complexities associated with the unfolding of political change: the emergent consequences at the macro level (i.e. the global level) of the dynamic interactions at micro or mezzo levels (i.e. intra- and inter-state levels).[1]

This paper proceeds as follows. Section I reviews the current state of the literature on the diffusion of central bank independence. Section II introduces a theoretical framework to explain diffusion of policy reforms in a globalizing context through the description of our agent-based model. Section III describes the research design. Section IV presents key results of the computer simulations, followed by the concluding section V.

[1] For useful reviews see Axelrod (1997); Cederman (2001); Macy and Willer (2002); Lustick et al. (2004); Lustick and Miodownik (2000; 2002).

I. Diffusion and the Study of the Spread of Central Bank Independence

In an interconnected world, national economies cannot be considered as isolated from the international context. Therefore, a study of a country's decision to reform its central bank without considering the behavior of other countries misses an important element of the reform process. A diffusion perspective provides a conceptual framework that allows us to account for the uncoordinated and interdependent aspects of administrative reform decisions and policy change more generally (Walker 1969; Gray 1973; Berry and Berry 1999). According to Evert Rogers, diffusion is "…the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers 1995, 5). David Strang adds that diffusion as "….any process where prior adoption of a trait or practice in a population alters the probability of adoption for remaining non-adopters" (Strang 1991, 325). Simmons and Elkins (2004) distinguish between three sources of convergence on new policies: uncoordinated behavior, similar responses to similar conditions, and coordinated action via negotiations. Only uncoordinated interdependence, they argue, is clearly a defining characteristic of diffusion.[2] Drawing on their insights and combining elements from Rogers, Strang, Simmons and Elkins, we define diffusion in this paper as

> *the process by which practices, ideas or institutions are communicated through certain channels over time in an uncoordinated manner among the members of a social system, where prior adoption of an innovation increases the probability of adoption for some of the population of the remaining non-adopters.*

This definition combines that social aspect of the innovation process as a communicative enterprise, emphasized by Rogers, with a specific condition of "uncoordinated interdependency" as emphasized by Simmons and Elkins. Another advantage of this definition is that while, following Strang, it emphasizes prior adoption, it goes beyond Strang in specifying directionality (i.e. whether diffusion increases or decreases the likelihood of adoption of an innovation by others). The

[2] The other two sources – similar responses to similar conditions and coordinated action via negotiation – reflect other structural elements involved in convergent behavior.

position taken in the current paper is that diffusion entails, at least for some of the remaining non-adopters in the population, a rise in the probability of adoption of the innovation. Lastly, the definition allows us to focus attention on the process of diffusion, not just on its outcomes.

The current paper is one of the first papers to apply a diffusion perspective to the study of central bank independence reforms. Polillo and Guillén (2005) make a pioneering attempt to apply large-*N* statistical methods to explicitly study the worldwide spread of central bank independence. Unlike others who focus exclusively on power-centered and economic motives to adopt the reforms (e.g., Cukierman et al. 1992; Goodman 1991), Polillo and Guillén work accounts for the coercive, normative and mimetic pressures that lead to the convergence on central bank independence. Their analysis supports the expectation that variation in states' decisions to adopt central bank independence reforms are correlated with states' exposure to external – coercive, normative and mimetic – pressures (which the authors associate with globalization). Domestic indicators, such as political and macroeconomic variables, by contrast, failed to explain variation in decisions to reform central banks.

Polillo and Guillén's work has great merit. Nevertheless, rewarding and popular as they may be, cross-national statistical studies have limited potential to explain certain of the aspects affecting a diffusion process. Not all aspects of decision making can be observed and measured, and not all the elements associated with an actor's behavior are reflexive and open to exploration by the more conventional research techniques. In addition, statistical techniques correlate variables in inputs and outputs and therefore are less appropriate for testing the workings of actual mechanisms of change; in other words, they are constrained in their ability to reveal the processes that take place. Formal models, although less empirical and direct, allow us to specify the various mechanisms affecting diffusion without the constraints of empirical data-collection. Thus, for example, Braun and Gilardi (2006) introduce a threshold-based expected utility theory of diffusion, which specifies the micro-foundations for actors' behavior and brings the various diffusion mechanisms into a common formal framework. The authors embed seven diffusion mechanisms – learning, competitive and cooperative interdependence, coercion, common norms, taken-for-grantedness, and symbolic imitation – within a simple theoretical

framework model in which an actor's expected utility depends on the payoffs and the effectiveness of the policy.

Polillo and Guillén (2005) and Braun and Gilardi (2006) offer distinct yet complementing ways to conceptualize and develop a diffusion perspective capable of explaining the emergence of global public policy in general and central bank independence in particular. This research employs a theoretical framework that is able to account for the widespread decision to increase central bank independence as well as the general process of global public policymaking, and to do so while describing diffusion as a process rather than an outcome. If diffusion is indeed a source of temporal and spatial convergence on central bank independence, our theoretical framework should be able to capture the uncoordinated interdependency of the decision to reform central banks, and offer possible explanations of three characteristics of the process, namely, the likelihood of an outbreak, the rate of adoption and the time to outbreak. The theoretical framework is developed using John Kingdon's streams model and more generally the garbage can model of policymaking (Cohen et al. 1972).

II. A Model of Policy Reform: Bringing Kingdon to the Domain of Diffusion

In an influential book titled *Agendas, Alternatives, and Public Policies*, Kingdon (1995 [1984]) introduces the idea that policymaking is a process that emerges out of the interaction between three different "streams": policy problems, policy solutions and politics. The Policy Problems Stream encompasses various problems, some of which emerge on to the public agenda, while others remain as potential, unrealized problems. The Policy Solutions Stream is where policy solutions are formulated. Some solutions survive for a considerable time while others do not. Survival of policy solutions dependents on the feasibility of the solution, on whether a state has the technical skills to implement it, and on whether the policy is morally acceptable, that is, implementation will not trigger opposition on moral grounds. The

Politics Stream identifies political circumstances that may facilitate (or inhibit) the implementation of specific policies, asking how a country's political elite will react to the specific policy solution.

In these different streams problems are looking for solutions but also, and paradoxically, solutions are looking for policy problems (see also Heimer 2008). Ongoing interactions between the streams result in various occasions for matching policy problems to solutions as well as the other way round. At times political circumstances allow for the opening of a "window of opportunities" that may facilitate the coupling of solutions to problems. Indeed, the coupling of the streams or the matching of solutions to problems, Kingdom argues, is the key to understanding agenda and policy change. The idea that a policy solution has a life of its own, not necessarily related to a certain problem, is a key feature also in Cohen et al.'s (1972) garbage can model and in the model we present hereafter. Policy solutions, like products, spread through policy communities as a result of coupling with problems that are ranked high on the public's agenda. Politicians turn to these policy communities for proposals that would be relevant to their concerns and might constitute a solution to various problems at the same time (Kingdon 1995, 55). The same policy can be used to solve different problems at various points in time and across space. Granting independence to a central bank, for example, may be the appropriate policy to combat inflation in one country, to appease internal political pressures in a second, and to pave the way to the grant of an IMF loan in a third.

Packages of problems and their suggested policy solutions emerge on the public agenda as "candidates" for policy reform, waiting for their political opportunity. Policy reform becomes feasible during limited periods of time in which a (political) "window of opportunity" allows the implementation of a policy solution.

Opening a "window of opportunity" does not constitute a sufficient condition for policy reform, but it is a necessary condition: if the window of opportunity is closed policy does not change. Policy change is subject to the balance between two forces, one spurring the policy solution and another opposing it. The term "threshold" was introduced by Granovetter (1978) to conceptualize these forces as the equilibrium point of cascading processes. Policy reform occurs when an equilibrium point is crossed within a window of opportunity.

The remainder of this section proceeds as follows. First, we introduce the building blocks of the model. Then we describe their attributes and rules of interaction. Lastly, we discuss the model's outcomes, which we will study in order to understand the characteristics of policy diffusion, i.e. the global spread of policy reform outbreaks and their rate and timing.

The model we introduce is specified as an agent-based model. Agent-based techniques are useful since they can be simulated on a computer. Computer simulations allow us to explore the consequences of formal models involving more than few variables, and are an effective way to scrutinize formal models. Careful design and operationalization of artificial worlds and meticulous experimentation with such formal landscapes allow researchers to examine theoretical explanations while undertaking complex "thought experiments" that are very difficult to conduct in the real world (Axelrod 1997).

Agents

Agents are the building blocks of the model. Each agent represents a hypothetical country. A country is associated with a binary variable c , which can

assume either true or false values. Thus, the value "true"[3] indicates that a country has reformed its policy, while "false"[4] indicates that it has not done so. $c_i(t)$ represents the value c for country i at time t. It follows that $c_i(t) \in \{0,1\}$.

A state's (i.e. agent's) "decision" to implement a policy idea is based on the interplay of three conditions: (a) whether the problem a particular policy addresses is very salient, i.e. ranked high on the public agenda; (b) whether the solution is considered to fit the problem by policy communities of specialists; and (c) the acceptance of the policy solution to the political establishment.

Agent's attributes

All agents update their propensity to reform concurrently on the basis of information about the saliency of the issue, policy fitness, and the acceptability of the policy to the domestic elite. While issue saliency and policy acceptability are determined solely by internal processes, policy fitness is an outcome of both domestic (internal) and global (external) information. Next, we discuss both internal and external information affecting the agents' behavior.

Internal information

Policy saliency[5] is the first of the three internal sources of information affecting an agent/country's behavior. Saliency levels range between minimum ($ms_{\min}=1$) and maximum ($ms_{\max}=100$) values; in other words $ms \in (1,100)$.

Saliency may change over time. Its value at a particular point in time *t+1* is affected by saliency at time *t* and by a random coefficient – r, $|r| \leq 1$, representing

[3] Coded as 1 (throughout the paper).

[4] Coded as 1 (throughout the paper).

[5] We treat Saliency of a problem as an ordinal concept varying according to objective and subjective measures.

changes in the saliency level from one time to another; it follows that $s_i(t+1)$ the saliency level s of a problem for country i at time t+1 is given by $s_i(t+1) = s_i(t) + r(ms_{\max} - s_i(t))$.

Policy fitness f is the second internal source of information affecting a country's behavior. Policy fitness levels range between a minimum value 1 and maximum value 100. Following Kingdon's theory, a higher fitness value implies that a policy solution is more likely to survive over time, thus having higher probability of being coupled with a problem and implemented as a policy.[6]

The level of fitness at time *t+1* is defined as a function of $f_i(t)$ that denotes the fitness level f of a solution for country i at time t. Domestic perceptions of policy fitness are subject in part to external influence. The change in fitness level is given by Δf .

Political acceptability[7] of a policy is the third domestic factor affecting a policy reform. Political acceptance *a* for country *i* at time *t* ($a_i(t)$) is specified as a Boolean function which can assume either "true" or "false" values. We selected a simple random behavior for the acceptance variable. Acceptability gets a random number with values of 0 or 1, where *r* is a random coefficient: $a_i(t) = r, r \in \{0,1\}$

External information

[6]Although the more general theory assumes the coexistence of many problems requiring a solution and many policy solutions that float in the problem and policy streams respectively, as mentioned above, we focus on global public policy, tracking a single (or similar) solution in different countries.

[7]According to Kingdon (1995 [1984]), acceptance of a policy within the political arena requires consensus. A consensus either exists or not. On this basis we decided to treat acceptance as a binary variable.

The external environment each country surveys for information (a proxy for geographical or ideological proximity) defines the "zone of influence" (Lustick and Miodownik 2006). Decisions made in these countries are taken into consideration and may in combination with the other factors, already discussed, alter the likelihood of policy reform.[8] The number of other countries that a country surveys before making a decision is captured by the notion of the zone of influence. The size of a country's zone of influence composed of its adjacent neighbors is defined as $Z = ((2d + 1)^2 - 1)$ where d is the distance between a specific country and the location of the most remote country it surveys. [9]

Changes in the policy fitness level (Δf) are a function of two conditions. The first is the difference between the average policy fitness in the zone of influence and a country's own internal policy fitness level. The zone of influence may be composed of countries that have already reformed their own policy and others that may have not. We assign a weight (w) indicating the influence of these neighbors. Countries that have already reformed their own policy have a positive weight on the likelihood of policy reform, while those that have not reformed their own policy reduce the likelihood of policy reform. It follows that the difference between the neighborhood's average policy and the domestic fitness level is:

[8] In the case of central bank independence, the local neighborhood includes allies, trade partners, and trade competitors (Polillo and Guillén 2005).

[9] When d = 1 a state collects information from the 8 states immediately surrounding or its "Moore Neighborhood" (see http://mathworld.wolfram.com/MooreNeighborhood.html). When d = 2 the number of states surveyed increased to 24; to 49 when d = 3, and so on.

$$\overline{nf_i}(t) = \frac{\sum_j w_j f_j(t)}{\sum_j w_j}, j \in neighbours(i), w_j \in \{w_{reformed}, w_{non-reformed}\}$$

Neighbors (*i*) is the set of all countries in the zone of influence of country *i*. This zone is defined as the region around country *i*, within distance of *d* or less on the grid, where *d* is the zone of influence radius. The zone includes ($Z = ((2d + 1)^2 - 1$).

The second condition affecting changes in policy fitness is the difference between a reform threshold *rt* that needs to be crossed to trigger interest in reforms and the policy's fitness in a country.

Changes in the policy fitness level Δf for country *i* at time *t* are noted as

$$\Delta f_i(t) = \left(\overline{nf_i(t)} - f_i(t)\right)\frac{(rt - f_i(t))}{rt}.$$

Policy reform rules

As agents begin to interact policy reform opportunities emerge. These "windows of opportunity", *wo*, open if two conditions combine: (a) a high problem saliency (beyond a saliency threshold *st*), and (b) a domestic political establishment that is ready to accept a specific policy reform. The window of opportunity for country *i* at time *t* can be either true or false, is notated as $WO_i(t) = (s_i(t) > st) \wedge (a_i(t) = true)$.

A country will reform its policy if a window of opportunity is open, and if the saliency and fitness level exceed the reform threshold. The reform condition for country *i* at time *t*, $RC_i(t + 1)$ is a Boolean function of whether or not a country has already reformed its policy, notated as

$RC_i(t+1) = RC_i(t) \vee (WO_i(t) \wedge (s_i(t) + f_i(t) > rt))$. We assume that policy reforms are irreversible. This assumption seems to be empirically plausible (at least in the case of central bank independence reform), but may not be true for all other types of policy change.

Model outcomes

So far we have discussed country attributes and the rules defining their interactions. The gist of this paper, however, lies in understanding the characteristics of policy diffusion, i.e., the global spread of policy reform outbreaks and their rate and timing.

We define $TA(t)$ as the total number of countries that have reformed their policy at time t. Given that reforms are treated as irreversible, it follows that:

$$TA(t+1) \geq TA(t) \quad \text{and} \quad TA(t) \leq number\_of\_countries .$$

The rate of adoption is defined as the average annual number of new adopting countries. Rate of adoption is measured in units of countries/year. An Outbreak is a case where the rate of adoption exceeds two countries per year.[10] Time to outbreak is defined as the period between the beginning of an observation and the point where the change in the rate of adoption is positive and maximal.

[10] This is an arbitrary decision that draws on empirical observation. In 1973, when the Bretton Woods system collapsed, 9 countries had an independent central bank. In 1987, before the beginning of the reform wave, 12 countries had an independent central bank. Thus, 3 countries had reformed their central banks during this 15-year period, yielding a rate of adoption of 0.2 countries per year. Since we define an outbreak as a sharp increase in the rate of adoption, we selected a value of two countries per year, which is an increase by an order of magnitude relative to the previous rate of adoption.

III. Research Design

In order to build and test the dynamic aspects of the model described above, we use NetLogo, a modeling environment for simulating natural and social phenomena (Wilensky 2007). NetLogo is particularly well suited for modeling complex systems unfolding over time. Modelers can set the behavior of independent "agents" and explore the implications of variations of attributes and behavior at the micro level for the emergence of unpredictable patterns at the macro level (for more details, see User Manual).[11]

To test the model we design a landscape defined as a cellular grid contained in a 15 X 15 matrix with 225 countries. Visually each country is represented by a square with three colored vertical bars (see Figure 2): the leftmost bar (red) represents the problem's "saliency level". The central bar (cyan) represents the solution's "fitness level" and the rightmost bar (green) represents the political "acceptance". A lighter shade of color represents a higher value of these variables. Once a state has reformed its policy the entire square becomes yellow. As agents begin to interact, saliency, fitness levels and policy acceptance are updated and changed following the interaction rules described above. These changes are illustrated graphically by the brightness changes of a country's color bars in Figure 2. Once the reform conditions are met a country's color turns yellow. The simulation continues for a limited number of time ticks or until all countries reform their policy.

[Figure 2 Here]

In the experiments we report on hereafter we pay particular attention to *Problem Saliency* and *Policy Fitness* scenarios[12] that may affect the likelihood and unfolding of policy outbreak in unpredictable ways. We evaluate agent interaction given two *Problem Saliency* scenarios. (a) The first scenario depicts situations where saliency either increases or decreases ($r \in [-1,1]$). These are situations where saliency fluctuates when other issues requiring urgent attention emerge or a previously salient

[11] A similar model was tested using PS-I (Lustick 2004) while results were quantitatively different they were qualitatively similar to those reported in this model.

[12] Note that problem saliency and policy fitness are variables which are characterized by a level, i.e. a number which changes according to the simulation rules. The rules dictating the behavior of the variables are set by the scenario parameter, as explained above.

problem disappears from the public's eye. (b) The second scenario depicts situations in which a problem becomes even more severe, ranking higher on the public agenda for an extended period, and is thus long-standing ($r \in [0,1]$). In either one of the two types of situation a high saliency level indicates that a problem attracts significant public attention, and is therefore more likely to trigger policy change. In addition we test two *Policy Fitness* scenarios. (a) The first scenario depicts situations where the policy idea is promoted by policy fitness communities. In this scenario changes to a policy's fitness levels are unidirectional and positive; thus, the policy fitness level can increase monotonically. Changes to policy fitness are given by $f_i(t+1) = f_i(t) + (\Delta f_i(t))^+$ [13]. (b) In the second scenario the policy fitness idea is in dispute amongst the experts; thus, changes are bidirectional and can be both positive or negative, allowing the policy fitness level to fluctuate. In this scenario change in policy fitness is notated as $f_i(t+1) = f_i(t) + \Delta f_i(t)$.

To study the behavior of the model we use varieties of parameters which receive different values across a simulation run as listed Table 1. We ran iterations across all 5,000 possible combinations of the simulation parameters. These values were selected to cover the parameter space while keeping the simulation runtime reasonable[14]. To control for variations in the outcome, which may be the result of stochastic elements included in the model, we ran each combination of parameter values five times. All in all, we collected information on a total of 25,000 iterations.

[Table 1 Here]

IV. Results

Before we present our findings on the characteristics of interest, it should be noted that the interactions in our model yielded a full convergence on every single run. In other words, all the iterations ended with all the countries reforming their

[13] f^+ is defined as follows: if $f > 0$ then $f^+ = f$, otherwise, $f^+ = 0$.

[14] A typical model run on an Intel® Core™2 6400@ 2.13GHz machine takes 18 seconds on average. A full run of 25,000 simulations requires almost three days.

policy.[15] This is not surprising since our model assumes, as explained earlier, that having once reformed states cannot revert to their previous policy.[16] Typically each run of the simulation yields a pattern resembling an S-shaped curve (see Figure 3). The shape represents the accumulated number of countries that reformed their policy at each time tick. The slope of the chord connecting the points with extreme curvature[17] values near the lower and the upper asymptotes represents the rate of adoption of policy reforms. Curves with a steep central portion indicate a policy diffusion outbreak – a situation in which the rate of adoption during the central portion of the S-curve (during the run) is significantly higher than the rate of adoption during the lower portion of the S-curve (early in the run). It goes without saying that a curve's slope and other properties are sensitive to parameter values set in any of the runs.

[Figure 3 here]

The data collected across the various runs reveals significant variations in the path to convergence of policy reforms, that is, long processes of convergence versus

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[15] In 7 cases the simulation reached the maximum time ticks of 5,000 before full convergence; however, the number of reformed countries at this point was 224 out of 225.

[16] The assumption seems to correlate with the observation that, having once reformed, no country had legally decreased the independence of its central bank. We intend to explore in future research the behavior of models that allow policy reforms to be reversed.

[17] A typical S-curve has three observable features: a lower portion which is characterized by a slow to moderate rise, a central portion which is characterized by a sharp rise of the curve, and an upper portion which, like the lower portion, rises slowly towards a possible maximum. To operationalize our dependent variables we need to identify the central portion of the curve and determine its beginning and end times. These points are defined as those where the change in the rate of adoption, i.e. the annual number of reformed counties, is maximal. These points are characterized geometrically on the S-curve graph as the points where the curvature of the curve reaches a local maximum.

short ones. Table 2 presents summary statistics of the convergence process, grouped by the possible scenarios of problem saliency and policy fitness. The average length of the convergence process and the average rate of adoption during the central portion of the S-curve (the sharply rising segment) are calculated for each combination of these parameters. The analysis of Table 2 reveals that convergence occurs sometimes very quickly, as quickly as after 21 time ticks. Yet the variation in time to convergence is substantial: sometimes it occurs after a period as late as 5,000 time ticks.

These differences between short and long processes can be taken as an indication of two types of policy reform spread. The short processes are shorter than the long processes by more than an order of magnitude, and their average rate of adoption in the central portion of the S-curve is much higher than the rate of adoption of the long processes. As such, the shorter processes fit our definition of an outbreak (see page 12), that is, cases where the rate of adoption is higher than two countries per year. Therefore, we will tag short processes as policy outbreak processes.

Discussing the length of the convergence process obliges us to set the scale between the simulation clock to real time, thus determining the number of days/months/years in real time which correspond to a simulation time tick. When measuring policy spread, we use units of years or decades since we are, after all, talking about a political process. The central bank reforms occurred in little more than a decade, leaving us with two options. Either we could match the rise time of the shorter processes to a decade of real time, thus setting a simulation time tick to one year (since the average rise time for these processes is 9–9.6 time ticks), or we could match the rise time of the long process to a decade; thus, the central portion of this process averages 413 time ticks. This suggests 40 time ticks to represent one year of

real time. If we do so, the duration of the central portion of the short processes, which represents the bulk of adoption cases, will be about ten days. Such time frames are inadequate for describing real world policy spread processes, especially those characterized by a high rate of adoption. This line of reasoning yields another interesting insight. In the long processes the average time during of the centre portion of the S-curve is 413 years. It is unreasonable to assume that in a dynamic world environmental conditions will remain constant for such an extended period of time. This may lead to an argument calling for widespread global policy only in short convergence process, while in long processes the spread of the policy will be fractional.

[Table 2 Here]

(a) The likelihood of an Outbreak

Table 3 presents results from logistic regression fitted to assess the relative effects of the simulation parameters at the outbreak of a policy reform process. The dependent variable *outbreak* is a dichotomous: outbreak = 1, no outbreak = 0. Three models were fitted: *model A* tests the impact of saliency, controlling for the effect of the various simulation parameters; *model B* tests the independent effect of a single variable of saliency; and *model C* tests the effect of the various simulation parameters excluding saliency.

Results reveal the importance of the existence of long-standing salient problems, which occur simultaneously in many countries, in a diffusion process that yields an outbreak. Both *model A* and *model B* have a very high rate of accuracy (% Correct = 99.2), while the correctness level of *model C* is only 50.7%, which is

effectively a random result. In other words, including saliency in the model turns a random predictor into a good predictor. This result suggests that saliency alone can be used as an outbreak predictor. An outbreak will occur when the saliency parameter is set to its second scenario, that is, highly salient and long-standing problems. As mentioned, problem saliency describes the behavior of the saliency level having two scenarios: one in which saliency of a problem's level varies frequently, and another in which problems are salient and long-standing. Indeed, in the simulation space there are only 184 outbreak events when saliency is set to fluctuating scenario – 1.45% from the total of outbreak cases – making this a rare outbreak event.

[Table 3 Here]

One possible "real world" interpretation of these results is that outbreaks are more likely to occur when highly salient problems flow in the policy stream without being matched to a policy solution. The existence of a problem that requires urgent attention increases the likelihood of reforming the policy, especially if the policy proposal seems particularly fitting the problem (i.e. high fitness level) and the proposed change is acceptable to politicians, thus enabling a window of opportunity to open. When this is the case across many countries, it is quite possible that we will witness an outbreak of a wave of global policy reforms. The absence of a parallel common problem in many countries, on the other hand, does not preclude any country from reforming its policy; but the chances of an outbreak of a global policy reform under such conditions will be quite slim.

Overall, the analysis of the data collected in these simulations attests to the importance of the existence of long-standing salient problems, which occur simultaneously in many countries, in a diffusion process that yields an outbreak. The implications are important to the theory of public policy, suggesting that problems

differ not only in terms of their saliency but also in terms of their persistence on the public agenda. Our simulation suggests that the theoretical treatment of the public policy process should distinguish between the two.

(b) Rate of adoption

An intriguing empirical fact of the 1990s central bank independence global reforms is the swiftness of the process. Indeed, while in the year 1990 only 19 countries had an independent central bank, in a period of 12 years the number of independent central banks sharply increased to 109 (see Figure 1). Thus, the average of adopting countries exceeded 7 countries/year, a significant number when referring to global policy adoption processes. This fact suggests that studying the characteristics of rate of adoption may provide a deeper understanding of sweeping policy adoption processes. To this end we carve the outbreak cases out of the simulation space and analyze them in isolation.

[Table 4 Here]

Table 4 presents results from multi-variable regression[18] fitted to assess the relative effects of the parameters on the rate of adoption. Three models are tested: *model A* assumes a single independent variable, namely, zone of influence; *model B* assumes all parameters to be independent variables; and *model C* assumes all parameters except zone of influence to be independent variables. Results suggest that both *model A* (F = 12794.859, df = 5) and *model B* (F = 57285.695, df = 4) are good

[18] The fitness parameter was found to be insignificantherefore excluded from the analysis. Since the fitness parameter is dichotomous (true, false), its exclusion allowed the use of multi-variable regression analysis.

predictors (R^2 = 0.857, 0.821) of the rate of adoption of policy reforms, while *model C* (F = 49.852, df = 1) is a poor predictor (R^2 = 0.016). Although other variables were found to be significant, their impact on the total fit of the model is small. The analysis of other models which do not include zone of influence shows that they are all poor predicators. We conclude that the most influential variable regarding rate of adoption is the size of the zone of influence

One possible "real world" interpretation of these results is that they demonstrate an emergent property of diffusion. As Granovetter (1978) anticipated, when the process of adoption begins it progresses rapidly since one country's reform decision affects many countries. This creates a chain reaction resulting in high adoption rates.

(c) Time to outbreak

Time to outbreak is defined as the period between the beginning of an observation (which in our case is the beginning of each simulation run) and the point where the change in the rate of adoption is positive and maximal. This point is the lower point of maximal curvature on an S-shaped curve. [19]

To understand the behavior of time to outbreak, we used sensitivity analysis, thus studying the effect of the most significant parameters – zone of influence, reformed influence weight and non-reformed influence weight on time to outbreak –

[19] Unlike with likelihood of outbreak and rate of adoption, the statistical analysis does not yield clear results. Since the statistical tests are applied to a model we designed, the relatively low figures cannot be justified by the existence of unknown factors that were not considered; rather, they may be a result of the fact that the model is not linear and the fact the time to outbreak is not determined by a single dominant parameter.

while fixing the values of all other parameters. A typical result is shown in Figures 4a and 4b. [20] Other parameter values provide similar graphs.

[Figure 4 Here]

The leftmost graph (4a) presents the dependency of the time to outbreak (y-axis) on zone of influence (x-axis). The graph shows that, as the value of the zone of influence grows, the latency of time to outbreak grows as well. Furthermore, the statistical scattering of the time to outbreak, reflecting the randomness in the model, decreases towards convergence. The rightmost graph (4b) presents the opposite dependency of the time to outbreak (y-axis) on reform influence weight (x-axis): as the value of reform influence weight increases the outbreak occurs earlier. While this result is expected, since a higher reform influence weight value increases the reform probability of the neighbors, the result regarding the zone of influence is an emergent property which cannot be directly derived from the agents' interaction rules.

Figure 5 describes three typical S-curves that were generated by changing the value of the zone of influence while keeping the values of all other parameters fixed. The x-axis is the time since the beginning of the simulation and the y-axis is the accumulated number of reformed countries at time t. It illustrates the combined effect of zone of influence on the properties of the outbreak: as zone of influence grows, the time to outbreak is delayed, while the rising portion of the S-curve becomes steeper, resulting in a higher rate of adoption.

[Figure 5 Here]

[20] A graph for non-reform influence weight was not included since it is reciprocal to the reform influence weight.

These results demonstrate how the transition from the domestic arena to the global arena affects policymaking. Increasing the zone of influence exposes more policy ideas; however, the process of crystallizing takes time, since the various opinions regarding policy practices must first converge. When this happens on a global basis, the adoption process begins in a sweeping manner.

Our model is far from encompassing the complexities of policy change processes. It is intriguing that even such a simple model can be useful to the study of policy reform outbreaks. However, more work is required to examine the extent to which the model and its consequences are applicable to other cases of global policy outbreaks. It is necessary to test whether the conditions which according to our model predict global policy outbreak indeed exist in other cases as well, and whether these conditions were not satisfied for policies that did not spread in the form of an outbreak.

V. Conclusions

In an interconnected world a decision to strengthen the autonomy of central banks and to adopt new policies more generally is not exclusively a domestic issue but a decision which is taken with reference to the decisions made by many other countries. Our model and the agent-based simulation that explores some features of this interconnectedness demonstrate how the propensity to adopt certain innovations is positively correlated with the adoption of others, and yield some insights on the conditions that may lead to an outbreak of adoptions of policies. We discovered that the saliency of a policy problem matters but not on its own. Rather, it matters in combination with the length of time that a policy problem floats in the policy stream. Thus, for policy reforms it is not only saliency that matters but also time. This aspect

is somewhat overlooked by current research in the policy field and needs to be addressed in empirical research designs (cf. Pierson 2000). We also suggest that the existence of long-standing salient problems on a global scale sets the stage for a sweeping global outbreak of a single policy solution, although the national policy problems and their severity vary or may have already been solved at the time of the reform. Here we demonstrate again a key insight of Kingdon's stream model. Solutions have lives of their own and are adapted to match and stick to various policy problems. Our diffusion perspective and the modeling of Kingdon's policy model demonstrates that one of the conditions that facilitate the adoption of these solutions is what others do. Windows of opportunities, therefore, are held open in the policy process by the sheer numbers of others who jump on the bandwagon of the reforms.

We have turned to agent-based simulation to explore options and gain insights into the process of central bank reform. The alternative, more common form of large-N statistics best explores the input–output correlations leading to reform but usually overlooks the synchronization of policy reform events as policies and collective decisions unfold. These statistical models can demonstrate that a policy reform in one country may increase the probability of similar reform in other countries, but do not tell us when, how fast, and through which trajectory and processes these reforms occur, nor do they reveal the assumptions of the actors and their cognitive decision making processes. With the help of the agent-based modeling we found that in the event of an outbreak, both rate of adoption and time to outbreak are positively correlated to the size of zone of influence from other countries. Furthermore, the size of the zone of influence plays a double role: on one hand, it increases the rate of adoption; on the other hand, it delays the outbreak. This emergent property of the

system cannot be predicted based on individual-level variables, and runs counter to the idea that globalization has by definition compressed time and space. Convergence may occur, yet not as fast as we would predict based on a one-dimensional understanding of globalization. This can be interpreted as if the implementation of a policy idea is delayed until a global consensus is achieved. This particular findings is an accordance with three major observations in the social science literature that have so far not been explored in tandem. First, policy gestation periods span up to 10 or 15 years, as already suggested by Sabatier and Jenkins-Smith (1993). Second, the findings are in agreement with Granovetter's (1978) threshold model, where in an interconnected world all are influenced by all, and the threshold is high before a reform outbreak occurs. Third, the findings are also compatible with the emphasis on the normative aspects of global change that are emphasized by sociological institutionalism in general and the world-polity approach in particular (Meyer and Rowan 1977; Meyer et al. 1997). We hope that future research will further explore the extent to which these various strands of the social science literature can be fully brought together so as advance theories of the policy process.

VI. References

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Table 1: Parameter values

Parameter	Value	Description	Simulation experiment space values
Saliency	Fluctuating / Long-standing	Determines which saliency scenario is in effect during a specific simulation run.	True, False
Fitness	Unidirectional and positive/ bidirectional	Determines which fitness scenario is in effect during a specific simulation run.	True, False
Reform threshold	1–100	Needs to be crossed to trigger interest in reforms	50,60,70,80,90
Saliency threshold	1–100	The window of opportunity can't open until the saliency level exceeds this value.	50,60,70,80,90
Reformed influence weight	1–10	Reflecting a positive weight on the likelihood of policy reform of countries that already have reformed their own policy.	1,2,3,4,6
Non-reformed influence weight	1–10	Reflect a negative weight on the likelihood of policy reform of countries that have not reformed their policy.	1,2
Zone of influence	1–9	The environment a country surveys for information.	1,2,3,4,9

Table 2: Convergence process statistics

Saliency scenario	*Fitness scenario*	*Minimum time tick of the last reform*	*Maximum time tick of the last reform*	*Average time tick of the last reform*	*Average duration of the center portion of the S-curve*	*Average rate of adoption (countries/year) in the central portion of the S-curve*
Fluctuating	Fluctuating	539	5000	1757	413	0.73
Fluctuating	Monotonic	555	5000	1748	413	0.70
Monotonic	Fluctuating	21	511	83	9.6	30.9
Monotonic	Monotonic	21	483	82	9	30.98

Table 3: Coefficients estimation of reform outbreak

	Model A– all		*Model B– saliency*		*Model C– all but saliency*	
	B	(s.e)	B	(s.e)	B	(s.e)
Saliency	11.566**	.331	11.334**	.325		
Fitness	.042	.145			–.001	.025
Reform threshold	–.008	.005			.000	.001
Saliency threshold	–.014**	.005			.000	.001
Reformed diffusion weight	.099*	.014			.003	.007
Non–reformed diffusion weight	–.147	.145			–.004	.025
Zone of influence	.140**	.023			.005	.005
Constant	–3.421	.672	–4.204		.052	.102
N	25000		25000		25000	
–2 log likelihood	2029.072		2080.314		34650.83	
χ^2	32623.443		32572.2		1.685	
Cox & Snell R^2	.729		.728		.000	
% Correct	99.2%		99.2%		50.7%	

**P<0.01, *P<0.05

Table 4: Coefficients estimation of rate of adoption

	Model A – all		*Model B – zone of influence*		*Model C – all but zone of influence*	
	B	(s.e)	B	(s.e)	B	(s.e)
Reform threshold	–0.187	0.030**			–0.187	0.014**
Saliency threshold	–0.069	0.048**			–0.069	0.014**
Reformed diffusion weight	0.249	0.164			0.249	0.117*
Non–reformed diffusion weight	–0.256	0.006**			–0.256	0.404
Zone of influence	7.394	0.006**	7.394	0.031**		
Constant	20.317	0.659	2.830	0.146	48.415	
N	12,528		12,528		12,528	1.595
R^2	0.857		0.821		0.016	
F	12794.859		57285.695		49.852	
df	5		1		4	

**p<0.01, *P<0.05

Figure 1: The spread of central bank independence

(Source: authors' database)

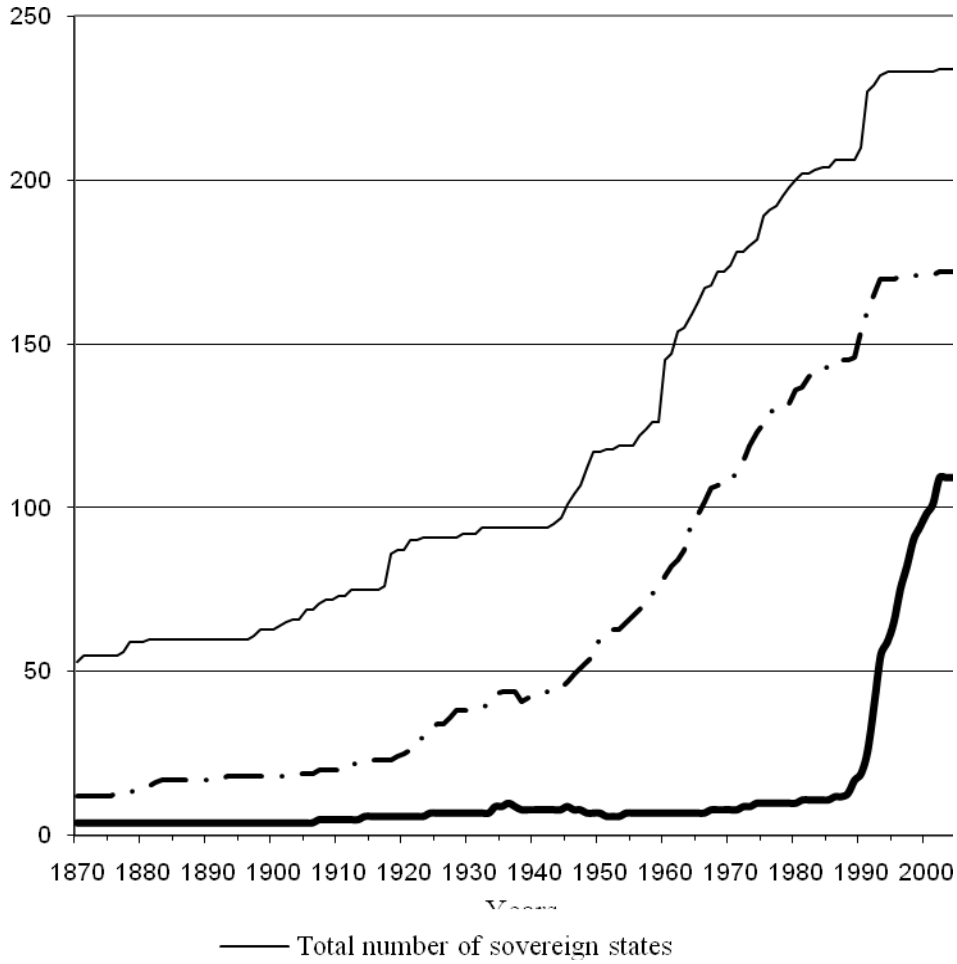


Figure 2: The simulation landscape

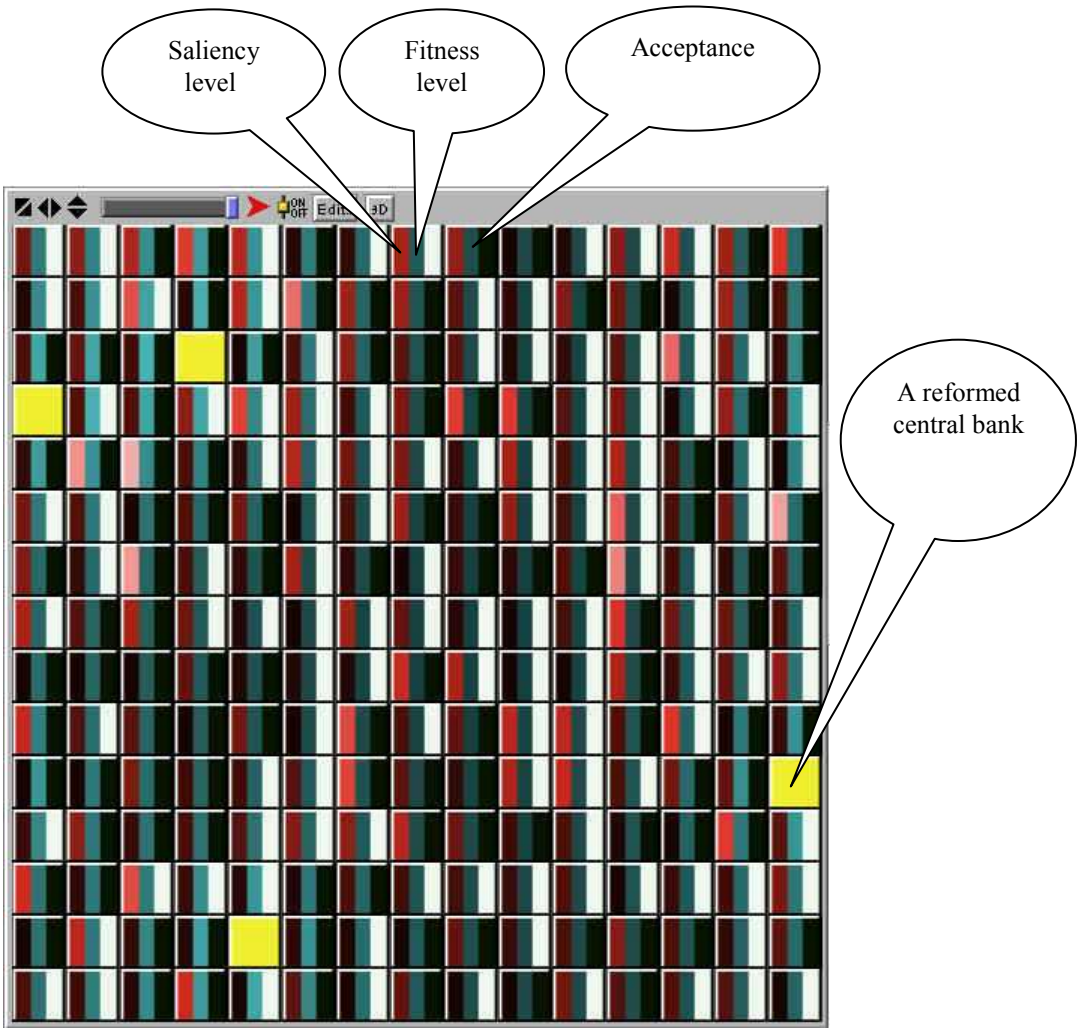


Figure 3: The S-curve features

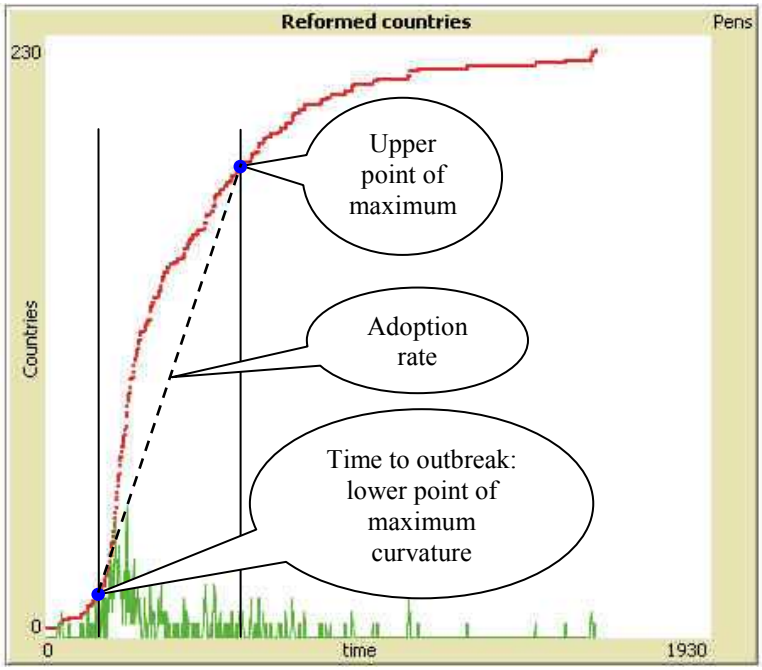
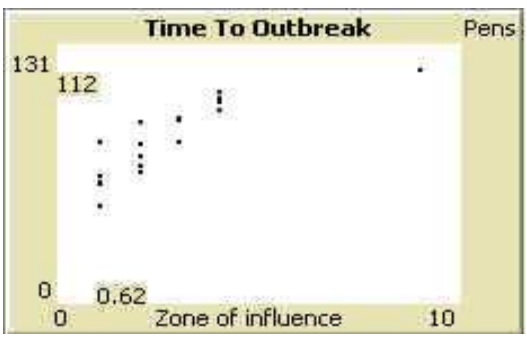


Figure 4a, 4b: Time to outbreak behavior

For 4a on the left: *fitness= fluctuating, reformed influence weight= 2, non-reformed influence weight=1, reform threshold=90, saliency threshold= 90*

For 4b on the right: parameters were fixed on *fitness= fluctuating, zone of influence= 4, non-reformed influence weight=1, reform threshold=90, saliency threshold= 90*



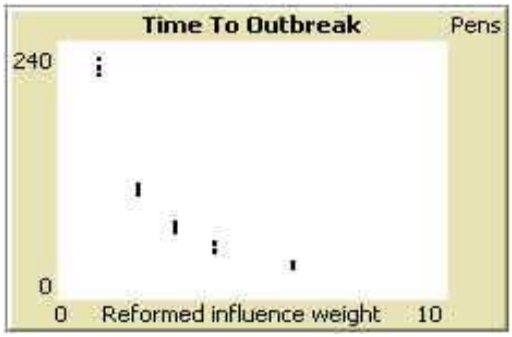
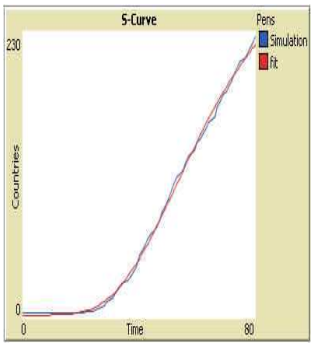
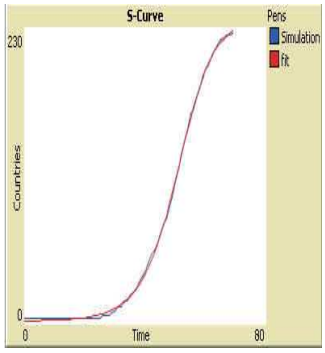


Figure 5: The impact of zone of influence on rate of adoption and time to outbreak

Zone of influence = 1



Zone of influence = 2



Zone of influence =4