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2001

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Abstract

The purpose of this paper is to verify experimentally the possibility and the degree of persistence of a self-fulfilling bank panic. Furthermore, we test various means to prevent or to curb it: the suspension of deposit convertibility, the “narrow banking” solution. We confirm the possibility of pure-panic bank runs as formalized by Diamond and Dybvig (1983). However, this situation remains rare. Partial and self-fulfilling bank runs represent a more general situation. That reinforces the idea of strong coordination failures as it was observed in the previous experimental literature. Panics are proved to be persistent phenomena which are difficult to prevent. However, it seems to be possible to curb them using a learning effect entailed by a temporary but enough long suspension of the deposit convertibility or using a narrow banking solution which enables banks to be more liquid.

Keywords : bank panic – self-fulfilling run (of depositors) – “pure-panic” bank run – panics’ prevention – suspension of convertibility – deposit guarantee – bank regulation – experimental study –

Research fields: *Theory of panic, banking economics, experimental economics*

JEL Codification : *G 20, G 21, G 28*

1. Introduction

In their history, the United States experienced many banking panics. Twelve of them took place between the beginning of the 19th century and the enactment of the Federal Reserve System in 1913 (Calomiris and Gorton, 1991). After the 1932-33 banking panic, the United States set up a federal insurance of deposits for commercial banks and Savings&Loans associations (FDIC and FSLIC, the 1933 Banking Act), event without precedent at the international level.¹ Through their mission of depositors' compensation, the first goal of these organizations is to prevent bank panics.

There is a general agreement to recognize their efficiency in panics' prevention and this idea is theoretically founded (Diamond and Dybvig, 1983 ; Engineer, 1989 ; etc.). Nevertheless, the commercial banks' debacle and especially S&Ls' one, at the end of the eighties, has revealed the limits of a deposit guarantee scheme (White, 1989 ; Dab, 1991). Most economists have thus criticized a financing of the deposit insurance with flat-rate premiums (not adjusted with the risk of each bank), responsible for moral hazard by accentuating the risk taking of banks. As a matter of fact, first of all, depositors with a too high deposit coverage slacken their vigilance, and so encourage the banks' direction to a more adventurous management. Secondly, a no-actuarial pricing of deposit insurance reinforces one such perverse effect because, for banks, the cost of a financing in insured deposits remains unchanged and equal to the unrisky rate, independently of the more or less risky use of deposits (Kareken and Wallace, 1978 ; Kane 1985, 1989, 1990 ; Flood, 1993 ; Thakor, 1993 ; Wheelock and Kumbhakar, 1995, etc.). In order to curb this perverse effect, some justified the existence of a prudential regulation in complement of the deposit insurance (among others, Buser, Chen and Kane, 1981 ; Freeman, 1988 ; Grossman, 1992, Karels and McClatchey, 1999), but whose effectiveness is discussed (Kim and Santomero, 1988, etc.).

¹ Since FIRREA (1989), the FSLIC has disappeared. The FDIC is now in control of the S&Ls' insurance fund.

Finally, on the whole, it can be concluded that the prevention of panics by the means of a deposit guarantee scheme becomes too expensive or that at least a trade-off must take place between the panics' prevention and the perverse effect of moral hazard (Hazlett, 1997). It explains the two new research ways quickly followed. First of all, theoretical works have been undertaken on information-based bank runs, i.e. runs of depositors moved by the perception of the future insolvency of their bank. They have completed and amended the precursory work of Diamond and Dybvig (1983), which has brought a theoretical foundation to the pure-panic bank runs (or self-fulfilling) and to the need for a deposit guarantee scheme to prevent them (Bryant 1980, Jacklin and Bhattacharya 1988 ; Alonso, 1996). Some of them have defended solutions of partial suspension of the deposit convertibility (Gorton, 1985a ; Chari and Jagannathan, 1988).

Secondly, historical works have examined various previous panics to determine the origin and so the nature of the bank runs (self-fulfilling pure-panic runs or information-based runs) and the means of preventing them : a partial or total suspension of the deposit convertibility with the setting up of a clearinghouse, a deposit insurance scheme (Gorton, 1985b ; Gorton, 1988 ; Calomiris 1989, 1990 ; Calomiris and Gorton, 1991 ; Grossman, 1992 ; Wheelock and Kumbhakar, 1995, etc.). Historically, banking panics seem to have corresponded, in a large majority of the cases, to information-based runs (Gorton, 1988 ; Calomiris et Gorton, 1991), even if this issue and that of the panics' prevention still remain a controversial topic.

In complement of a confrontation, already largely undertaken, between theoretical works and the historical facts, this paper proposes a new way to test the existing models, that allowed by experimental economics. More precisely, this work tries to answer the following questions: is a self-fulfilling banking panic (like in Diamond and Dybvig, 1983) possible, or at least can it be experimentally observed ? Do mechanisms of suspension of deposit convertibility, or a "narrow banking" solution make it possible to prevent or to curb this type of panic ?

This experiment tests a contextual repeated n-player coordination game with two Pareto-ranked Nash equilibria, which illustrates the depositors' behavior with regard to the withdrawals from their bank. The bank run is supported by the Pareto-dominated Nash equilibrium and is so the result of a coordination failure. Generally, previous experiments bear on repeated 2-player games with two or several Pareto-ranked Nash equilibria (for a survey see Cooper,1999). We so propose a contextual experiment on an other type of coordination game. But we globally draw the same conclusion as the earlier experimental work which demonstrates that in certain experimental environments two kinds of coordination failure occur : a Pareto-inferior Nash equilibrium is reached or ex post disequilibrium outcomes are observed. The present experiment reinforces the relevance of the second kind of coordination failures.

Section 2 presents the Diamond and Dybvig's theoretical framework (1983) and its developments. We stress on their conception of a Pareto-diminated Nash run equilibrium for the stage game which becomes an evolutionarily steady state in the repeated game. Section 3 explains the experimental protocol and its ability to test the previous models. Section 4 gives the results and section 5 concludes.

2. The theoretical framework²

The theory of banking intermediation, and with it that of banking panics, experienced a renewal at the beginning of the eighties thanks to Diamond and Dybvig's work (1983). Within the same framework, subsequent researches confirm the effectiveness of the deposit guarantee in the prevention of panics (Engineer, 1989). But, more are those which, while improving the initial model, rehabilitate the partial suspension of deposit convertibility (Chari, 1989 ; Wallace 1988, 1990 ; Armaos, 1992 ; Selgin, 1993).

² For the details on the formalization and the results' proof, see Diamond and Dybvig (1983) and Temzelides (1995).

Diamond and Dybvig (1983) insist on the instability of the banking activity insofar as the liquidity service (socially beneficial) provided by the bank to its depositors leads intrinsically to a possibility of banking panic. That is due to the fact that the bank enables each depositor to smooth its plan of consumption by giving him the possibility of consuming more immediately and, on the other hand, less later. Such a system functions only if the depositors (of type 2), inclined to a late withdrawal and consumption (in period 2) do not come to withdraw immediately, i.e. at period 1. In that case, the bank won't be able to refund the whole of the depositors, but only a part of them, slightly higher than the number of depositors (of type 1) normally coming to withdraw in period 1.

As a matter of fact, initially, when the deposit contract is decided ($T = 0$), the depositor does not know if he will prefer to withdraw quickly his funds (type 1 depositor) or if he will prefer to withdraw later (type 2 depositor). The type of investment (or technology), of which the depositor has individually at his disposal, allows him to obtain only 1 unit (of consumption good), in period 1 ($T = 1$), and $R > 1$ units, in period 2 ($T = 2$). However the depositor, who is risk adverse with a coefficient of relative risk aversion higher than 1, wishes to be insured against the risk to be of type 1, i.e. prefers to smooth his plan of consumption over the two periods. The depositors, all supposed identical *ex ante*, then rely on their bank.³ The latter allows the t % of them proving to be of type 1 to withdraw a sum x_1 higher than 1, in period 1, and the $(1-t)$ % of them turning out type 2, to obtain a sum lower than R , in period 2. The bank, which has the same possibilities of investment that a simple depositor, will not be so able to pay back more than N/x_1 depositors ($< N$) in period 1 if the economy includes N agents.

³ Each depositor gives the bank his endowment of 1 unit, which becomes a deposit of 1 unit. With N agents in the economy, the bank has N units.

It is so enough that each type 2 depositor (or patient depositor) anticipates that the other depositors will come to withdraw in period 1, so that he behaves in the same way.⁴ Thus, once in this logic of self-fulfilling panic, each depositor does not find beneficial to change his strategy if the others don't do it. Indeed, he knows that the bank provides a sequential service of the liquidity, i.e. the first to arrive will be the first served and that those last arrived will not be able to withdraw anything more. This panic thus constitutes a pure and strict strategy Nash equilibrium (pareto-dominated) and it is not based, contrary to information-based runs, on any particular information showing a future insolvency of the bank.

Another strict Nash equilibrium (pareto-dominant) happens when type 2 depositors do not become impatient to withdraw and thus do it in period 2. Such equilibrium occurs if each one of them anticipates that the others will withdraw in period 2. In Diamond and Dybvig's model, type 2 depositors derive the same utility from an immediate or a later consumption. Consequently, as their level of withdrawal or consumption can be more important by waiting, they increase their level of utility (by no means reducing that of the others) by consuming in period 2.

In addition, by using evolutionary game theory, Temzelides (1995) introduces dynamic in this framework by proposing a repeated version of Diamond-Dybvig's game on an infinite horizon. In each period, there are m possible states, where a state represents the number of (type 2) individuals who withdraw in period 2. The evolutionary framework implies that the best strategy of the previous period is imitated and so its representation increases in the population of patient agents. Temzelides (1995) shows that, in this coordination game, the deterministic dynamical system has two pure steady states which correspond to the optimal and the panic equilibrium of the stage game.

⁴ As impatient agents (type 1) always withdraw in period 1, only patient agents (type 2) are "strategic" players. Consequently, we study the coordination game played by m patient agents choosing either to withdraw in period 1 or to wait until period 2. So, there are $N - m$ impatient agents in this economy.

To solve the problem of multiplicity, a Markov dynamical system is used. One comes to the result that banking panics remain rare events insofar as the fraction of impatient people (type 1) is low, that the banking Asset (or the technology) is not too illiquid and that the individuals do not have a too accentuated risk aversion (and thus do not ask for a too marked smoothing of their consumption). The combination of the two last conditions expresses the fact that the “transformation” activity of banks should not be too marked.

3. The experimental protocol

The object of this section is to show how the theoretical model can be tested by the experiment and how the experiment is capable to answer our questions on banking panics and the means of their prevention and their treatment. The experiment must reflect the essence of the model, but it can wander from it for a better understanding of the raised questions. Therefore Friedman and Sunder (1994, p. 11-12) write in their work : *«your goal should be to find a design that offers the best opportunity to learn something useful and to answer the questions that motivate your research (...). A laboratory experiment should be judged by its impact on our understanding, not by its fidelity either to reality or to a formal model »*. In addition, the reader will find the instructions of the experiment in appendix 1. Let us specify beforehand that the experiment, which proceeds on computer terminal, was undertaken on 8 groups of 10 participants, that is to say in all 80 participants. It is made up of 4 successive experimental sessions.

The experiment is only interested in the strategic depositors, according to the expression of Temzelides (1995), i.e. in the depositors likely to panic (those of type 2, “patient depositors”). The participants have the choice to withdraw an amount of money from their current account, open in the same bank, at one of the two opening periods of the bank windows: “period 1” or “period 2”. In the first experimental session, for example, if less than three of them withdraw in period 1, they receive 40 ECUS⁵ in period

⁵ Experimental Currency Unit.

1 and 45 ECUS in period 2. If withdrawals in period 1 exceed the number of three, the bank can no longer satisfy any additional withdrawal, in period 1 or in period 2. The bank is then illiquid. In this context, only the first three participants who chose to withdraw in period 1 will be able to do it and the others will lose all. This rule of the « first arrived, first served » accurately renders the sequential service of the liquidity which is retained by Diamond and Dybvig (1983).

In the experiment, the amount received by the participants, in each period, is fixed by the experimenter. Therefore, it is not at all a question of testing the willingness of the depositors to smooth their plan of withdrawals (or of consumption), all the more since in our experiment “period 1” and “period 2” are simultaneous. It is supposed, as in Diamond and Dybvig (1983), that the depositors are *a priori* indifferent between the two periods, but that, preferring more than less, they will wish to withdraw (45 ECUS or 60 ECUS according to sessions) in period 2 rather than (40 ECUS) in period 1 (from the moment when they anticipate that the others will act in the same way). The pareto-optimal Nash equilibrium is reached when all the participants withdraw in period 2.

It is supposed that a “**partial run**” occurs when at least one participant withdraws in period 1. As a matter of fact, this panic is caused by the anticipation of this or these individuals, sometimes wrongly, that the other participants will panic as well, leading the number of withdrawals in period 1 beyond three. When less than 3 or 7 participants (according to the sessions) choose period 1, the “partial run” is described as **non self-fulfilling**. This run becomes **self-fulfilling** when more than 3 or 7 participants withdraw in period 1 and that some of them cannot be paid back. A **total and self-fulfilling run**, also called «**pure panic**» **bank run**, takes place when the 10 participants withdraw in period 1. This situation corresponds to the run equilibrium of Diamond and Dybvig (which is a pure and strict Nash equilibrium). It is also an evolutionarily steady strategy which leads to a steady state for the repeated game (Temzelides, 1995). The diametrically

opposed situation, where none withdrawal in period 1 is observed, has the same characteristics of equilibrium and long run stability (« **non-panic** » situation).⁶

The four sessions of the experimental protocol is made up of 30 rounds. That makes it possible to test experimentally the dynamics of the Diamond and Dybvig's model, such as it was proposed by Temzelides (1995). The first experimental session puts the individual under conditions which, according to Temzelides, increase the probability of a panic : slight differential between the withdrawal in "period 1" (40 ECUS) and the withdrawal in "period 2" (45 ECUS), a low number of withdrawals in period 1 from which the bank can no longer refund somebody (3 withdrawals). These two elements constitute the experimental parameters, which vary during experimental sessions and which characterize the banking institution. The space of time between two rounds (or rather between two successive choices) corresponds to a suspension of the deposit availability.⁷ It is in fact the moment when the individuals learn from last rounds.⁸

The second experimental session repeats in an identical way the first one. This session aims at testing the effectiveness of a longer suspension of deposit convertibility (like the « banking holiday » during the 1932-33 banking crisis in United States). As a matter of fact, all the first experimental sessions have finished on a strong panic, except for one group. The additional reading of the instructions by the participants, for a new experimental session, is used for a cut. The objective is to test if this suspension enables the participants to reach the payoff-dominant equilibrium, one of the two steady states in the long run. This mechanism corresponds in reality to a more or less long period of banks' closing. By giving us the possibility of dissociating the learning effect of a

⁶ For more details, see appendix 2.

⁷ The gain of the participants at the end of a session corresponds to the average withdrawal on the 30 rounds.

⁸ Moreover, the suspension joined to the repetition of the rounds allows the learning and so suspension acts on participants' behavior by a learning effect. The goal of this experiment is not to study thoroughly the learning effect. A wide experimental literature exists on this topic.

modification of the institution, this session makes it possible to evaluate the capacity of a suspension of convertibility to stimulate a « non-panic » behavior among the depositors.

But, generally, during a period of suspension of the deposit availability, the State and/or the Supervisory Authorities bail out certain banks. It is what the two last sessions make it possible to render because the learning effect produced by the preceding experimental sessions interferes with the change in institution. Thus, by increasing the withdrawal in “period 2” from 45 ECUS to 60 ECUS, the third experimental session, tends to increase the interest of the participants for this period. That limits the incentive of the participants to panic and reduce the probability of a panic (as the Temzelides’s work shows it).

In other respects, the fourth experimental session increases the capacity of the bank to resist a panic. As a matter of fact, the threshold of withdrawals in period 1 from which the bank becomes completely illiquid raises. The participants anticipate that it is necessary now that more than 70 % of the depositors yield to panic so that the bank closes its counters. Temptation to panic is thus much less strong. One approaches there to a solution of « narrow banking » : it constitutes the extreme case where the bank places all the depositors’resources in extremely liquid assets in order to be able to refund all of them, in any situation.

3. The results

The results are presented in the form of 12 observations of which some are deduced from the others. For each one of these observations, using tools of descriptive statistics, one shows first how they are proved correct as far as the 8 samples or 8 groups of participants are concerned. This first stage gives results which remain however valid only for the 80 participants of the experiment. The second stage consist in inferring these results to the population of students from which the groups are drawn (statistical inference). Only nonparametric tests are used because they do not require the respect of strong assumptions on the observations (Siegel and Castellan, 1988). Let us specify that

these tests are all detailed in appendix and that their results are presented for a Type I error of 0.05 and 0.01. However, the results are thereafter significant at the 95% significance level.

OBSERVATION 1: whatever the experimental sessions, the “pure panic” run, in the meaning of Diamond-Dybvig (1983), is an unusual phenomenon. That means that the situation, corresponding to evolutionary steady state supported by a strict and pareto-dominated Nash equilibrium and where the coordination failure is strongest, is seldom observed.

Even in session 1, a total run (of the 10 participants) only occurred during 8 rounds. As appendix 2 gives details of it, that represents 3% of the rounds played by the 8 groups of participants, that is to say on the whole 240 rounds. This number decreases as the sessions go by to disappear in session 4 (2% of the rounds in session 2 and 1% in session 3).

OBSERVATION 2: the general case in session 1 is that of rounds where a partial and self-fulfilling run occurs (number of withdrawals in period 1 between 4 and 9). It is at the same time a situation of strong coordination failure and disequilibrium which prevails in this session. This observation is the same even if the withdrawal in period 2 increases from 45 ECUS to 60 ECUS.

This case is found on 196 rounds, that is to say on 82 % of the rounds of session 1. Moreover, the average number of withdrawals per round reaches 6.23 with a standard deviation of 2.45 and a median of 7 (appendix 4). The coordination failure is thus relatively strong seeing that the general case is close to a total run. Let us stress that the coordination failure grows with the average and the median of the number of withdrawals in period 1 and reaches its maximum when these two indicators are at 10. In this session, one seems to be in a situation of medium period under the influence of the basin of attraction of the (long-run) panic steady state. As a matter of fact, one cannot render a long-run situation thanks to a session which is made up of 30 successive rounds or at

least the long run corresponds in experiments to a series of rounds higher than about thirty. Moreover, it is necessary to be careful about the nature of the steady state because the only time when such a state was reached in a group in session 1, it was the state which corresponds to the pareto-dominant Nash equilibrium (no withdrawals in period 1) - see appendix 20-7 -.

An other experiment on 7 groups of 10 participants has been undertaken where, in the first session, the subjects can withdraw 60 ECUS in period 2. The Mann-Whitney test proves that the average number of withdrawals in period 1 (per round) is the same between the two experiments.

OBSERVATION 3: the situation of partial and self-fulfilling run tends to be accentuated during the session 1 rounds. In a corollary way, the coordination failure increases between individuals as the rounds go by.

As the general upward trend of graph 1 illustrates it (appendix 5-5), the number of withdrawals in period 1 of the 80 participants increases regularly during the 30 rounds of session 1. Moreover, appendix 5-1 shows that the average number of withdrawals per round in period 1 is on an increasing trend during session 1. It is the same for the median and the mode. As specified in appendix 6, the Cochran test detects a difference in individuals' behavior on the first 15 rounds of the session and beyond. Over a shorter period, i.e. on a number of rounds lower than 15, the test does not show any significant change. That expresses the progressive tendency of the individuals to choose period 1, inclination perceptible by a Cochran test on a set of at least 15 rounds. In the Cochran test meaning, it means that the probability for an individual of choosing "period 1" varies from round to round when one takes into account at least the first 15 rounds of the session. This last test finds moreover a difference in behavior statistically significant at the threshold of confidence of 0.95 over periods 11 to 15 and periods 21 to 30 (for a Type I error of 0.053 in this last case).

These first results are reinforced by the appendix 8 which gives the results of the one-tailed McNemar applied to the comparison of the individuals' behavior between any two rounds of the first 10 rounds of session 1. This test detects a change in individuals' decision from period 2 to period 1 between the first round and following beyond the 9th round. Appendix 9 extends this last result by showing that the change in behavior between the round 1 and all rounds subsequent to the 9th round is statistically significant. However, the McNemar test does not detect any change in behavior between each successive round of the session 1 and that since the first round of the session (appendix 7). In complement, the change-point test, applied to the series of the numbers of (80) subjects' withdrawals in period 1 during the 30 rounds of session 1, detects a possible change in behavior at the 12th round but considers it non significant (appendix 12).

The whole of these results reinforce the idea of a perceptible change in behavior a little before the middle of the session. It is by no means a strong change in the behavior, but a simple reinforcement of a present trend in favor of period 1 choice.

OBSERVATION 4: the withdrawals in period 1 are cyclic during the 30 rounds of session 1.

The graphs of appendices 20-1 to 20-8 show the cyclic character of the number of withdrawals in period 1 during the 30 successive rounds of session 1 for the various subjects' groups. The run test of randomness confirms this fact by detecting short-period cycles (on average 4-5 periods) for the whole of the groups or more precisely for the populations from which these groups are drawn.

More precisely, such as it is built, the test concludes that there is a great and statistically significant number of regroupings (runs) of rises and falls in withdrawals in period 1 between two rounds. As each run is composed on average of 2 or 3 rises or successive falls, it may be deduced from this that cycles of 4-5 periods exist. But let us specify that in the first place the test enables to say that the rises and the falls of the

number of withdrawals in period 1 between two rounds do not occur in random order during session 1. For complementary details on the question, see appendix 16 (table 1).

Unfortunately, this test is not able to detect medium-period cycles which also seem to affect the groups (appendices 20-1 to 20-8). The run test of randomness, applied now to the 80 participants, also shows the fact that short-period cyclical fluctuations significantly influence the number of withdrawals in period 1 during the rounds of session 1 (appendix 16, table 2).

OBSERVATION-COROLLARY 5: From observations 1 to 3, one concludes that a short suspension of the deposit availability applied to the banking institution of session 1 is an insufficient means to prevent and stop a bank run.

However, starting from the 22nd round, group 7 is in an almost “non-panic” situation (see appendix 20-7). Even if this phenomenon was observed only in one of the eight groups, there is a need to carry out a new experiment where the session would be made up of 60 rounds for example. The present experiment only shows that a mechanism of convertibility suspension of do not entail a convergence in 30 rounds of the session 1 banking institution on a non-panic situation. But nothing indicates that beyond this number such a mechanism cannot be effective to stop a panic.

OBSERVATION 6: session 2 proves that a suspension of greater extent after a short suspension and repeated 29 times (in session 1) makes it possible to stop definitively the panic started in the banking institution of session 1, or at least during 22 consecutive rounds.

As illustrated by the graphs of appendices 20-1 and 20-2, groups 1 and 2 continue to panic in session 2. On the other hand, groups 3 to 8 stop panicking during the first half of the session (appendices 20-3 to 20-8). One will observe the very strong resemblance between the groups 3 to 6 which respectively stop panicking in the 5th, 6th, 6th, 8th, 2nd and 17th round. Let us note, that for group 8, only one withdrawal in period 1 does take

place on and after the second round. As appendix 13 shows it, these abrupt changes are considered statistically significant by the change-point test.

As detailed by appendix 8 , the McNemar test, applied to the first 10 rounds of the session 2 taken 2 by 2, detects a change from period 2 to period 1 between the first round and following rounds only beyond the 6th round. Appendix 9 extends this last result by showing that the change in behavior between round 1 and the almost all later rounds after the 6th round is significant. From the second to the 7th round, the change is statistically significant only between these rounds and the 9th or the 10th round. From the 8th round, no change in behavior occurs between these rounds and their following since almost all the participants maintain their choice of period 2 (appendices 8 and 10). The change is not directly perceptible between a round and its 6 following rounds insofar as on average a participant by round changes his choice in favor of period 2. The progressiveness of the change, in the meaning of the McNemar test, is confirmed when one applies this test to compare the individuals' choice between two successive rounds because no change is detected, even for the first 10 rounds (appendix 8).

It is however necessary to underline the relative feature of the concept of progressiveness insofar as, in 6 groups out of 8, the run dies out on average in 5 rounds. In this respect, appendix 17 details the symptomatic behavior of subjects who belong to group 3 to 8 and who have initially chosen to withdraw in period 1. As a matter of fact, 95 % of them, that is 21 participants out of 22, still choose period 1 until at the most the 8th round for adopting almost definitively thereafter a withdrawal in period 2. Let us note that practically 50% of the participants, who followed such a type of behavior, switch their behavior from the second round. As detailed by appendices 14-1 and 14-2, the change-point test used on the series of the (80) participants' decisions during session 2 shows the strong concentration of the changes in individuals' behavior between the first and the seventh round. As a matter of fact, 85 % of the changes in behavior happen during this period, including 37 % only for the second round. In order to still reinforce these results, the change-point test, used for the number of withdrawals in period 1 of the

80 participants during the 30 successive rounds of session 2, shows a lasting and significant change in individuals' choice starting from the eighth round (appendix 12).

OBSERVATION 7: a long suspension of the deposit availability applied to the banking institution of session 1 (or 2) does not permit to prevent any run.

Appendices 5-1 and 5-2 give a first intuition of this result: the mean and the median of the number of withdrawals in period 1 observed in first round on the 8 groups are respectively in session 1 and session 2 of 4.62 against 3.75 and 4.50 against 4.00. For each session, the standard deviation of the first round is the lowest of all the rounds and is almost equal between the two sessions (1.218 against 1.299). That thus expresses the strong concentration of the observations around the mean and thus the similar groups' behavior in the first round of each session and between the first rounds of the two sessions. This result can be inferred on the level of the population from which the samples are drawn thanks to the McNemar test which compares round by round sessions 1 and session 2. No change in individuals' behavior takes place between the first round of session 1 and session 2. On the other hand, the test confirms the change in individuals' choice in favor of period 2 for all the other rounds (appendix 11).

OBSERVATION-COROLLARY 8: from observations 3 and 5, it is deduced that the growth of a bank panic phenomenon happens in a way more gradual than its disappearance. Its disappearance requires a real abrupt change in the depositors' behavior: either this abrupt change occurs and panic dies out almost instantaneously (in some rounds), or it continues to be propagated. The learning effect in the group thus depends on its capacity to cause collectively (and without any preliminary communication) such a behavior of abrupt change. The "long duration" suspension proves to be a good means of this learning.

OBSERVATION-COROLLARY 9: from observations 6 and 7, one can conclude that a long suspension of the deposit availability applied to the banking institution of session 1 (or 2) is a good curative means but that it fails in its preventive role.

OBSERVATION 10: session 3 and 4 make it possible to prevent a panic from occurring. The combination of the learning effect generated by short and long suspensions of the deposit availability and modifications of the banking institution leads to an almost “non-panic” situation.

It is necessary as a preliminary to observe that this experiment does not enable us to distinguish the precise role of the banking institution from that of the learning effect obtained by the repetition of the rounds in the preceding sessions, and that is all the more true for session 4. As a matter of fact, let us recall that session 3 modifies the banking institution by increasing the gain obtained in period 2 (interest rate on deposits) and that session 4 corresponds to a «narrow banking» solution (the threshold of withdrawals in period 1 from which no more participant can be refunded goes up from 3 to 7). The object of a future experiment will be precisely to analyze the impact of these institutions by neutralizing the learning effect and thus the effect of a suspension of the deposit availability.

However, some results can be already suggested by taking the precaution not to allot them only to the new form of banking institutions. During these two sessions, and contrary to the second, panic is prevented as early as the first round. As a matter of fact, the McNemar test shows that there was a change in individuals' behavior in favor of period 2 choice between the first round of session 1 and that of sessions 2 and 3. This change is confirmed for the 29 later rounds (appendix 11). On the other hand no change is detected from one round to another during the two sessions, as that was besides the case in sessions 1 and 2 (appendix 7).

For session 3, the Cochran test does not find any change between rounds whatever the set of rounds considered by the appendix 6. And, in particular, the test considers that individuals have the same probability of choosing period 1 as period 2 in each of the 30 rounds of the session. On the other hand, session 4 presents the same type of profile as session 2. The Cochran test concludes that there is no overall change in individuals'

behavior during the first 7 rounds. However, when one extends the set of rounds beyond the 7 first, one concludes from it that the probability of choosing period 1 or period 2 is different according to rounds. The change-point test, used for the number of withdrawals in period 1 of the 80 participants during session 4, detects on the sequence of the 30 observations a significant change-point at the 13th round (appendix 12). And the graph of this sequence of observations well shows that panic dies out completely from this 13th round. It would be nevertheless erroneous to deduce that session 4 was more «panicking» than session 3 (see for more details observation 11 hereafter). Indeed, the phenomenon observed in session 4 was not present in session 3 because, in this last session, group 1 panicked throughout the session on a slightly ascending trend (change from period 2 to period 1). And to some extent, this phenomenon came to thwart the trend in the other groups of a change from period 1 to period 2 during the rounds of the session.

OBSERVATION 11: as the four sessions go by, the run situations become blurred, i.e. become less frequent and less intense, and almost disappear in fourth and last session.

As appendix 4 shows it initially, the average number of withdrawals in period 1 in a round does not cease decreasing as the sessions go by to go down from 6.23 to 2.31, then 1.20 and to finish finally to 0.38. One will notice a strong dispersion around the mean of the number of withdrawals in period 1 during session 1 (standard deviation: 2.45), which is explained by the cyclical fluctuations of this variable during rounds of this session. The median indicates besides that 50 % of the rounds had a number of withdrawals in period 1 higher than 7. Dispersion is even stronger for sessions 2 and 3 (respective standard deviation of 3.13 and 2.59). It expresses the fact that 2 groups on 8 still continued to panic in session 2 and one in session 3, this difference in behavior between groups introducing a certain variability between rounds at the aggregate level. On the other hand, no more group panics in session 4, which explains the very strong regrouping of the observations around the average (standard deviation of 0.58). One will

observe finally the very strong fall in the median during sessions which has gone down from 7 to 1 to finish to 0 in the two last sessions.

In a still very aggregate way, it will be observed that during the 2400 rounds in which the 80 individuals took part in each session, they chose period 1 in 62 % of the cases in session 1, in 23 % in session 2, in 12 % in session 3 and in 4 % in session 4 (appendix 4). This preference for the period 2 during sessions is again confirmed when one analyzes the number of times (or rounds) in a session that the 80 participants chose period 1. As a matter of fact, as detailed by appendix 18, 6.25 % of the individuals chose less than 3 times period 1 in session 1 whereas they are 60 % in session 2. 85 % in session 3 and 90 % in session 4. On the contrary, 56.25 % of the individuals withdrew in period 1 in more than 60% of the rounds (or more than 19 times) in session 1 against 17.50 % in session 2, 8.75 % in session 3 and 1.25 % in session 4.

In other respects, the individuals' behavior tends to be stabilized during sessions on the choice of period 2, and that is particularly true for the two last sessions. Thus, the change-point test used for the 80 individuals detects significant changes in behavior for 40 % of the individuals in session 1, 17.5 % in session 2, 6.25 % in session 3 and 8.75 % in session 4 (appendix 15, table 1). In addition, one will observe the high increase between session 1 and session 2 of the number of participants who have a perfectly uniform behavior in all the rounds by having chosen only period 2. This number continues to grow between session 2 and session 3 to stabilize itself in session 4. As a matter of fact, the percentage of these participants is 2.50 % in session 1, 42.50 % in session 2, 70 % in session 3 and 75 % in session 4 (appendix 15, table 2). In complement, one will notice that 17.50 % of the participants chose less than 10 times period 1 during session 1 whereas they are 75 % in session 2, 86.25 % in session 3 and 96.25 in session 4 (appendix 18).

When one observes the number of withdrawals in period 1 during the rounds (appendices 2 and 20-1 to 20-8), it is obvious that the situation which corresponds to the pareto-dominating Nash equilibrium and where coordination is perfect becomes the most

frequent case as the sessions go by. As a matter of fact, whereas 3 % of the rounds of session 1 correspond to this situation, it is the case of 45 % of the rounds of session 2, 70 % of the rounds of session 3, 67 % of the rounds of session 4. It will be also noticed that the cases of partial and non-self-fulfilling run, corresponding to situations of disequilibrium and low coordination failure, increase starting from session 2. Thus, one finds this situation in 12 % of the cases in session 1, in 29 % of the cases in session 2, in 18 % of the cases in session 3 and in 33 % of the cases, in session 4. In this kind of run, those implying the weakest coordination failure are the most frequent in sessions 2, 3 and 4 (appendices 3-1 and 3-2). As a matter of fact, it respectively accounts for 74%, 84% and 89 % of the runs of this type. One will observe as the sessions go by the opposite movement for the situations of partial and self-fulfilling run (medium to strong coordination failure) and of self-fulfilling and total run (total coordination failure).

Thanks to the Wilcoxon signed ranks test, one can infer these results for the samples at the level of the population (appendix 19, table 1). As a matter of fact, this test proves that the number of withdrawals in period 1 in each round is significantly higher in session 1 than in all the later sessions, in session 2 than during session 3 and 4, in session 3 than in session 4. One can thus conclude from it that, as the sessions go by, panic becomes blurred. In complement, the Spearman correlation coefficient, used to measure the degree of association of the numbers of withdrawals in period 1 during the 30 rounds of two sessions, considers a correlation significantly negative between session 1 and sessions 2 and 4. That renders the fact that in session 1 the number of withdrawals in period 1 increases as the rounds go by, whereas the opposite phenomenon occurs in sessions 2 and 4. On the other hand, one concludes to a correlation significantly positive between sessions 2 and 4. That reinforces the idea that the profile of the 2 sessions is identical: strong decrease in number of withdrawals in period 1 in the first half of the session and withdrawals almost null thereafter. On the contrary, one will observe the correlation significantly negative between sessions 2 and 3, which proves the rather flat profile of the number of withdrawals in period 1 during session 3, contrary to session 2 (appendix 19, table 2 and appendix 5-5).

OBSERVATION-COROLLARY 12: from observation 11, one deduces that the bank is less and less illiquid as the sessions go by.

As proved by appendix 2, whereas 85 % of the rounds lead in session 1 to a situation of illiquidity of the bank, i.e. a situation where the bank is not able to satisfy the withdrawal of some depositors, this proportion falls to 27 % in session 2 and 13 % in session 3. It disappears completely in session 4. Let us note that, even if the threshold of illiquidity of the bank were fixed at 7 withdrawals in period 1 for session 4, this one is not worried any more by runs higher than 3 withdrawals. That means that, even for a threshold of illiquidity fixed at 3 withdrawals in period 1 as in the preceding sessions, the bank would not have experienced any situation of illiquidity in session 4.

5. Conclusion

This paper has explored experimentally the possibility and the degree of persistence of a self-fulfilling bank panic. Furthermore, we have tested various means to prevent or to curb panics : suspension of deposit convertibility (or availability), “narrow banking” solution. This experiment bears on a particular repeated n-player coordination game with two Pareto-ranked Nash equilibria, which illustrate the depositors’ behavior as far as the withdrawals from the banking system are concerned.

We confirm the possibility of pure-panic bank runs (self-fulfilling and total bank runs) as formalized by Diamond and Dybvig (1983). However, it remains a seldom observed phenomenon. Partial and self-fulfilling bank runs, which are due to strong coordination problems, represent a more general situation. That reinforces the idea of coordination failures as it was observed in the previous experimental literature. Panics are proved to be persistent phenomena which are difficult to prevent. However, it seems to be possible to curb them using a learning effect entailed by a temporary but enough long suspension of the deposit convertibility or using a narrow banking solution which enables banks to be more liquid.

Even if this experiment does not deal with information-based runs, it relativizes the results of some historical studies which reinforce the theory of information-based runs developed by the same authors (Gorton, 1988 ; Calomiris and Gorton, 1991). In this last theory, the depositors are uninformed about the bank asset risk. Consequently, they are inclined to panic when they perceive adverse news which modify the perception of this risk and so the probability of their bank failure. These news are generally a macroeconomic indicator of recession of the real activity and the panic occurs when this indicator exceeds a threshold.

At the opposite, self-fulfilling panics are sunspot equilibria. This means that every piece of information, which leads to forecast that the others will run, can be at the origin of a panic. The problem is so a lack of confidence in the behavior of the other depositors. As a matter of fact, this kind of panic is due to a strong coordination failure between depositors. The present study proves that self-fulfilling panics are a recurrent experimental phenomenon. Of course, in order to reinforce this result, it would be necessary to undertake this experiment with various kinds of banking institutions (payment in the period 2, threshold of illiquidity) and experimental environments (number of rounds per session, number of subjects per group).

Other developments should be also interesting to explore. First of all, this experimental framework permits also to test the passage from a non-panic situation to a panic situation. Secondly, this experimental design enables a study of the effect of various levels of deposit coverage on the panic behavior of depositors. As a matter of fact, in the previous experiment, it is supposed that depositors lose all in situation of illiquidity of the bank. It is thus easy to introduce a partial coverage, corresponding to a payment of a sum between 0 and 40 ECUS. The full coverage case is trivial in this experiment and constitutes a reference point. A first exploration of these questions is proposed in Madiès (2000).

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APPENDIX 1:THE INSTRUCTIONS OF THE EXPERIMENTAL PROTOCOL

You take part in an experiment in economics at the end of which you will be able to gain a certain amount of money. Your profits depend on your decisions but also on the decisions of the other participants in the experiment. All decisions that you will have to take and all available information will pass on through the computer terminal, which was allotted to you.

In this experiment, you are a group of 10 participants and each one must withdraw a sum from your account, opened in the same bank. The experiment is made up of four successive experimental sessions and you will preserve this same role during all the experiment. You will be in interaction with the same partners during the various rounds composing each experimental session. **You are asked not to communicate with the other people taking part in the experiment.**

FIRST EXPERIMENTAL SESSION

This first session is made up of 30 successive rounds.

1) What is your choice in each of the 30 rounds ?

The participants must choose to withdraw their money in one of the two periods of the bank's counters opening: period 1 or period 2. You have one minute to make this choice.

2) What is the sum you can withdraw in each period ?

The amount that you can withdraw in each period depends on the behavior of withdrawal of the other participants, who, like you, can withdraw in period 1 or in period 2.

When less than three participants withdraw in period 1, the bank individually offers them 40 ECUS and those choosing period 2, 45 ECUS. Beyond three withdrawals in period 1, the bank can no longer satisfy any additional withdrawal, in period 1 or in period 2. Who will be then the three satisfied participants ? One enforces the rule of the " first arrived, first served ". This rule means that the first three participants who chose to withdraw in period 1 will be able to do it and that the others will lose all.

The following table permits to visualize what has been just explained and thus indicates the sum that you will perceive in each period.

Number of participants wishing to withdraw		PERIOD 1			PERIOD 2		
in Period 1	in period 2	Number of participants who can be	Number of participants who are not	individual amount of the withdrawal	Number of participants who can be	Number of participants who are not	Individual amount of the withdrawal
0	10	0	0	–	10	0	45
1	9	1	0	40	9	0	45
2	8	2	0	40	8	0	45
3	7	3	0	40	7	0	45
4	6	3	1	40 or 0	0	6	0
5	5	3	2	40 or 0	0	5	0
6	4	3	3	40 or 0	0	4	0
7	3	3	4	40 or 0	0	3	0
8	2	3	5	40 or 0	0	2	0
9	1	3	6	40 or 0	0	1	0
10	0	3	7	40 or 0	0	0	–

3) How to withdraw your money in the period that you chose?

During 1 minute, you can click, at any moment, on the icon " period 1 " if you wish to withdraw in period 1 or on the icon " period 2 " if you wish to withdraw in period 2. If you don't make a choice during the accorded time (1 minute), you cannot withdraw any more for the round (and the amount of your withdrawal is thus null). An indicator is

on the screen in order to inform you of the time which remains to make your decision. A message appears in the 10 last seconds to specify you that a decision must be made.

Once that you click on one of the two icons, this one disappears.

4)When is a round finished and how does one move from a round to an other?

A round is finished when the 10 participants made their decision. As each participant has one minute to choose, the round cannot last more than one minute.

At the end of each of the 30 rounds, you are informed:

- of the amount of the withdrawal in the period that you chose,
- of the number of people who came to withdraw in period 1 and in period 2.

The whole of this information appears as rounds happen in a table, which remains permanently on the screen.

A new round begins when the two icons "period1 " and "period 2" appear again on the screen.

5) A the end of the experiment, you will be paid on the following basis:

For each experimental session, your monetary profit corresponds to the average amount of your withdrawals during the various rounds of the session and it is indicated to you at the end of each session. Your total monetary profit (on the whole of the experiment) corresponds then to the sum of the profits in each experimental session and it is paid to you at the end of the experiment.

If you have questions concerning what you have just read, please raise the hand, we will come to answer your questions. During this experimental session, would you please not ask a question nor speak in a loud voice.

Thank you again to respect all these instructions.

QUESTIONNAIRE

Before deciding, can you answer the following questions, even if you are not sure of the answers.

A) **Two** participants (among the 10 participants) withdraw in period 1.

- What amount can a participant withdraw in period 1 and in period 2 ?
- What is the number of non-paid back participants in each period ?

Answers:

Period of the withdrawal	amount of the withdrawal	Number of participants who are not reimbursed
Period 1		
Period 2		

B) **Four** participants (among the 10 participants) withdraw in period 1.

- What amount can a participant withdraw in period 1 and in period 2 ?
- What is the number of participants who are not paid back in each period ?
- If participants are paid back in period 1, on which criterion will they be repaid ?

Answers:

Period of the withdrawal	amount of the withdrawal	Number of participants who are not reimbursed
Period 1		
Period 2		

The criterion of repayment in period 1:

C) **Eight** participants (among the 10 participants) withdraw in period 1.

- What amount can a participant withdraw in period 1 and in period 2 ?
- What is the number of participants who are not paid back in each period ?
- If participants are paid back in period 1, on which criterion will they be repaid ?

Answers:

Period of the withdrawal	amount of the withdrawal	Number of participants who are not reimbursed
Period 1		
Period 2		

The criterion of repayment in period 1:

SECOND EXPERIMENTAL SESSION (INSTRUCTIONS)

(Same table)

THIRD EXPERIMENTAL SESSION (INSTRUCTIONS)

This table changes.

Number of participants wishing to withdraw		PERIOD 1			PERIOD 2		
in Period 1	in period 2	Number of participants who can be	Number of participants who are not	individual amount of the withdrawal	Number of participants who can be	Number of participants who are not	Individual amount of the withdrawal
0	10	0	0	–	10	0	60
1	9	1	0	40	9	0	60
2	8	2	0	40	8	0	60
3	7	3	0	40	7	0	60
4	6	3	1	40 or 0	0	6	0
5	5	3	2	40 or 0	0	5	0
6	4	3	3	40 or 0	0	4	0
7	3	3	4	40 or 0	0	3	0
8	2	3	5	40 or 0	0	2	0
9	1	3	6	40 or 0	0	1	0
10	0	3	7	40 or 0	0	0	–

FOURTH EXPERIMENTAL SESSION (INSTRUCTIONS)

Number of participants wishing to withdraw		PERIOD 1			PERIOD 2		
in Period 1	in period 2	Number of participants who can be	Number of participants who are not	individual amount of the withdrawal	Number of participants who can be	Number of participants who are not	Individual amount of the withdrawal
0	10	0	0	–	10	0	45
1	9	1	0	40	9	0	45
2	8	2	0	40	8	0	45
3	7	3	0	40	7	0	45
4	6	4	0	40	6	0	45
5	5	5	0	40	5	0	45
6	4	6	0	40	4	0	45
7	3	7	0	40	3	0	45
8	2	7	1	40 or 0	0	2	0
9	1	7	2	40 or 0	0	1	0
10	0	7	3	40 or 0	0	0	–

