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INSTITUTIONAL MEMORY, INERTIA AND IMPULSIVENESS

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Institutional Memory, Inertia, and Impulsiveness

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Abstract

Institutional Memory, Inertia, and Impulsiveness

This paper examines how imperfect institutional memory affects organizational decisions. In our model, a manager knows his firm's previous actions but (owing, *e.g.*, to turnover) not the rationale for these actions. If the environment is stable, we find that a firm that has followed an old policy long enough and then loses memory generally should optimally exhibit excess *inertia*, defined as a higher probability of following old policies than a full-recall firm. On the other hand, if the environment is volatile or if firm has followed its prior policy only briefly, previous decisions are not very informative, and the firm can exhibit excess *impulsiveness* (*i.e.*, be more prone to follow new information signals). This suggests that organizational routines and cultural norms should be more extensive and effective in stable environments than in volatile ones. The model implies relationships among observable variables such as the frequency of policy changes, managerial turnover, the quality of record-keeping, the history of project choices, and the volatility of the external environment.

...the most radical revolutionary will become a conservative on the day after the revolution.

Hannah Arendt, *The New Yorker*, September 12, 1970.

Be not the first by whom the new are tried,
nor yet the last to lay the old aside.

Alexander Pope, *An Essay on Criticism*, 1711.

When I was younger I always conceived of a room where all these [strategic] concepts were worked out for the whole company. Later I didn't find any such room.... The strategy [of the company] may not even exist in the mind of one man. I certainly don't know where it is written down. It is simply transmitted in the series of decisions made.

General Motors executive quoted in Quinn (1980).

1 Introduction

An organization's projects, policies, routines, and cultural norms are often firmly entrenched even when the rationales are not evident. Projects and policies are often maintained and even escalated despite opposing information (see, *e.g.*, Arkes and Blumer [1985]). Similarly, the *non*-adoption of a potential activity or system often continues despite the arrival of favorable information. For example, bureaucracies lay down rigid rules that discourage innovation. Several authors have argued that firms commonly use high hurdle rates (above the cost of capital) that discourage undertaking new projects (see references in Dixit [1992]).

It seems plausible that such inertia is most likely to be overcome when a new manager arrives. Consider, however, the replacement of IBM's CEO John Akers by RJR Nabisco CEO Louis Gerstner on April 1, 1993 following a period of dramatically poor performance. Gerstner surprised most observers by deciding *not* to make a radical change in course: "...three months into the job, Gerstner has made it clear that he has no intention of reconstructing IBM. Instead, the man everyone saw as the Great Changemeister is determined, for the moment, to carry out a set of policies put in place by none other than the much-maligned Akers."[1] Such inertia may have made good sense. As an

[1]See "At IBM, More of the Same–Only Better? In Sales and Strategy, Louis Gerstner Is Following John Akers' Path," *Business Week*, 7/26/93. According to this article, Gerstner is "...still following

executive with a marketing background from outside the computing industry, Gerstner may have initially lacked the expertise needed to evaluate IBM policies.

Similarly, even ardent reformers sometimes perpetuate the policies of the regime they replace. Policy continuity is even more prevalent (if less dramatic) after routine transitions not motivated by managerial failure. Managerial and employee turnover for retirement or personal reasons occurs regularly without significant policy shifts or change in organizational culture.

The optimal degree of organizational inertia is a central issue for corporate strategy.[2] Why do some firms have cultures of dynamic change, while others are more static? Organizations could sometimes be *over*-sensitive to new information. Indeed, it is quite common to hear complaints about "weather-vane" leaders who allegedly flip with every shift in the breeze. Several competing theories of inertia are discussed in Subsection 5.2, but we are not aware of any work that addresses the opposite phenomenon, *impulsiveness*, or the factors that favor inertia versus impulsiveness. We attempt here to remedy this gap in the literature.[3]

The firm's decision to maintain or depart from current policies should balance newly arrived information against the imperfectly-remembered pool of old information. Because of limits on the transmission and storage of information, individual members of large organizations seldom know the full reasons for most decisions. Thus, institutional memory can fail even if individual managers, like elephants, never forget.[4] Our approach assumes that past *actions* (policies, routines) are remembered perfectly, while past *information signals* are remembered poorly. Whereas justifications are easily forgotten, or perhaps never even communicated, *actions* are visible, salient, and memorable.

Our analysis examines how the coarseness with which past policies summarize past

through on Akers' two-year-old restructuring." "Lou is not rushing to make significant changes in vision," according to Gerald M. Czarnecki, IBM's new head of human resources.

[2]See for example the excellent overview of Rumelt (1994). He argues that managers should take into account a firm's own inertia and the effect an action will have on future inertia, and that in practice strategic success is often due to the inertia of competitors as much as the cleverness of the innovator.

[3]Rumelt's overview opposes organizational inertia (persistence) to *plasticity*, a readiness to respond appropriately to environmental change. Thus, inertia (or lack of plasticity) is an obstacle to optimal behavior. This categorization implicitly excludes the possibility that firms sometimes place *undue* weight on new information (impulsiveness) and hence adjust behavior *too* readily.

[4]The importance of information loss is demonstrated by the amount of resources devoted to information preservation through such devices as recorded minutes, memos, secretaries, accounting systems, expert systems, groupware programs, and deferral of employee retirement.

information distorts manager's decisions. While poor recall of actions destabilizes the *status quo* (we need to remember old policies to perpetuate them), in our model poor recall of past *signals* (rationales for decisions) can sometimes help *preserve* the *status quo*.

The model examines a one-shot memory loss. In the *partial recall* scenario, pre-transition-date actions but not signals are recalled. The benchmark for gauging whether inertia or impulsiveness is excessive is the alternative *full recall* scenario in which both actions and signals are accessible. If a firm with partial recall is on average more likely, in the face of new information, to continue old policies than a regime with perfect memory, it exhibits *excess* inertia (or is *inert*); if the partial recall firm is more likely to discontinue old policies, it exhibits *excess* impulsiveness (or is *impulsive*).

Whether there is inertia or impulsiveness depends on how heavily a manager should optimally weigh his own new information relative to the information he extracts from previous decisions. Suppose that an initial manager had undertaken a project and that his replacement—without access to his predecessor's information—must decide whether to undertake a similar project.[5] Since the new manager cannot be sure how strongly his predecessor's information favored the original decision, even if he receives a new opposing signal he should rationally continue the old project if the presumed favorable information of his predecessor outweighs the new signal. In contrast, a continuing manager who only barely favored the old project should switch after a new opposing signal.[6]

On the other hand, suppose that the initial manager had been in place only for a short time and/or that the gains to adopting a project are stochastically changing through time. Then no strong inference should be drawn from the predecessor's action, because (1) the initial manager may have been close to the borderline, and (2) even if the old choice was correct at the time, it may no longer be correct now. Thus, a replacement manager may rationally follow his own signal regardless of the firm's past actions. In

[5]For concreteness, we phrase the discussion in terms of the memory loss associated with a new manager routinely replacing an initial manager (rather than other sources of amnesia). We are not focusing on pressured managerial transitions designed to bring about change, which involves other complicating effects.

[6]Although this provides a possible explanation for why change may be slow after a transition, it does not explain why analysts would be *surprised* by policy continuity in the IBM/Gerstner example given earlier. A possible explanation is that analysts *ex ante* placed undue weight on some forces outside our model that favor change after a major transition, such as superior expertise of the new manager, or the desire of a new manager to "hit the ground running" to signal superior expertise.

contrast, a continuing manager would in some cases know that the old information was quite strong, and in such cases would follow old actions over new signals.

Our framework therefore provides implications about several determinants of inertia versus impulsiveness, including the volatility of the organization's environment, how long policies and executives have been in place, and the quality of the firm's information systems. The remainder of this paper is structured as follows. Section 2 provides the basic model, which leads primarily to excess inertia. Section 3 discusses two extensions that can lead to excess impulsiveness. Section 4 discusses implications of the model based on the value and sources of institutional memory. Section 5 compares the model to other theories of tradition, rules, and organizational inertia. Section 6 concludes.

2 The Basic Model

This section provides a multiperiod model in which organizational amnesia reduces the probability of policy shifts (action reversals) after a new manager arrives.

2.1 A Specific Decision Setting

Consider a firm faced with a sequence of four identical investment project opportunities. The true value of each opportunity, which is constant through time, can be either good (value state $\phi = G$) or bad (value state $\phi = B$), with equal ex-ante probability. Project payoffs are perfectly correlated across projects but are not observed until the end of the game. Instead, a manager can only observe a single signal, H or L, each period. If the underlying state is good, the current manager observes signal H with probability p ($p > 0.5$), and L with probability $1-p$. If the underlying state is bad, the manager observes L with probability p and H with probability $1-p$ (see Table 1). Conditional upon the value state, the successive signals are assumed statistically independent.[7]

Table 1 Here

[7]An alternative interpretation of the model would define actions A and R as expanding or shrinking a project that is already in place, state G and B as a higher and lower probability of getting a high payoff *each period*, and a signal H or L as an immediately observed higher or lower payoff. Note that information in our model is obtained even when a manager rejects.

In each period, the current manager chooses a publicly visible *action*, either to *adopt* the project (A), *reject* the project (R), or *abstain* from decision ($\emptyset$). Net payoffs are such that the manager adopts the project if state G is more likely than state B, rejects if B is more likely than G, and abstains when G and B are equally likely.[8] Appendix A (Table 3) provides a simple payoff structure such that this behavior is optimal.

We compare two scenarios. In the *full recall* scenario, both actions and signals are retained (*i.e.*, the initial manager I stays in place for all four periods and retains access to his old information). In the *partial recall* scenario, the new replacement manager N can recall the three actions taken prior to the transition date (period 4), but *not* the signals of his predecessor. The quality of N's decisions is always inferior to that of a continuing I, because I's information about the past dominates.

Table 2 Here

Table 2 describes actions in both scenarios. N can perfectly infer the information held by I only if in period 2, I abstained.[9] With the same information set, N acts like a continuing I. However, when I does not abstain, I's information is not fully revealed by his actions, so N's information is inferior to that of a continuing I. In this no-abstention sequence of events, I either rejects for all three periods (RRR) or adopts for all three periods (AAA). To determine whether managerial replacement causes excess inertia or impulsiveness, consider N who receives a single opposing signal (H after RRR, L after AAA). Uniform rejection (RRR) could have resulted either from LLL or LLH. N can reason that if the sequence was LLH, a single H signal would make him indifferent, but if the signal sequence was LLL, he should still reject. Given these two possibilities, he should reject (line 4 in the table). A continuing manager, in contrast, can fine-tune his behavior by rejecting after LLL but abstaining after LLH. As indicated in the table, I abstains (and thus changes course) in the LLH case, while N maintains. (An analogous argument applies for $AAAL$.) Thus, the firm has excess inertia under the new

[8]For simplicity we examine a symmetric model, but this leads to the possibility that the manager is indifferent. Introducing the (somewhat artificial) option of abstaining simplifies the algebra and discussion by eliminating randomization or tie-breaking rules. We have derived similar results when there is no option of abstention. Furthermore, when signals are not perfectly symmetric and discrete, individuals would almost never be exactly indifferent and thus almost never abstain.

[9]The first action matches the first signal (adopt if H, reject if L). Since the second action leads to abstain, it reveals an opposing second signal. The third action matches the third signal.

manager.[10]

2.2 A General Decision Setting

This section examines a setting with any number of periods either before or after the potential memory loss (manager switch) date. All other assumptions of the previous example are maintained.[11] Define the *signal state* of I at time t as the difference between the number of H and L signals that he observes, $s_t \equiv n_H - n_L$ (in t draws). For example, if I observed $HHLHL$, he is in signal state +1 at date 5. Under this definition, the manager's signal state follows a conditional Markov process.[12] Given the value state (G or B), the transition probabilities from signal state s to $s+1$ or $s-1$ are just the conditional probabilities of another H or L signal being observed. The tie value $s_t = 0$ is the point where the manager switches from either A or R to $\emptyset$. Appendix A derives the probability of reaching $s_t = 0$ given an information set.

2.3 Scenario Comparison

Suppose I has been in place for M periods. For N, observing only I's past actions (adopt, reject or abstain) is equivalent to observing only whether the Markov signal-states at dates 1 through M were above, below or equal to 0. We call abstention an *action switch*, since the manager shifts from strongly preferring one action to being indifferent. Whenever an action switch occurs, N can perfectly infer I's signal state.

All computations—both for I and N—are conditional upon having observed a sequence of exactly M uninterrupted adopt decisions in the last M periods prior to the memory loss date. For two reasons, this is without loss of generality. First, adopt and

[10]Following the sequence $LLHH$, N continues to reject, while I abstains. Because I is indifferent, amnesia does not produce a welfare loss. However, after one additional period I may switch to adopt, while N does not and thus amnesia causes an expected welfare loss.

[11]The state/signal structure provided is similar to state/payoff structures in parts of the contingent claims and option pricing literature. By increasing the number of periods per unit time and decreasing per-period signal accuracy, our analysis can be applied to a setting in which signals are conditionally continuous log-normal processes, and new actions are selected at every instant of time.

[12]A Markov stochastic process has the property that the system can be in one of only a limited number of states, and there are fixed transition probabilities with which the system shifts from one state to another. Thus, so long as the state is known, the history by which the system arrived at that state is irrelevant.

reject are symmetric, so we can focus on adopt. Second, we examine only strings of the same action, because the signal state is zero whenever there is an act of abstaining.[13]

It is useful to generalize the notion of signal state to apply to either **I** and **N**.

Definition *The* **equivalent state** *for a new or continuing manager is the minimum number of consecutive opposing signals (L-signals for an adopting manager, H for a rejecting manager) required for the manager to switch action to abstain or beyond.*

For a continuing **I**, the equivalent state is the same as the signal state.[14]

2.4 Investment Choices with Full Recall

We now compute the probability that a continuing **I** with full recall switches within t periods, after just having adopted for M periods. Let $A(k,t,p)$ (calculated in Appendix A) be the probability that **I** or **N** who starts in equivalent state k receives enough low signals to make an action switch (abstain or beyond) at least once within t periods.

Proposition 1 Full Recall Switch Probability

The probability that the initial manager, having made exactly M successive adopt decisions, switches action at least once within t periods is

$$r_{\mathbf{I}}(M,t,p) = Pr(G|M)\left[\sum_{k=1}^{M} c(k;M,p)A(k,t,p)\right] + Pr(B|M)\left[\sum_{k=1}^{M} c(k;M,1-p)A(k,t,1-p)\right],$$

where $c(k;M,p)$ is the probability that he is in state k given exactly M prior adopts.

The first term conditions on the value state being good. If the value state is good, **I** can be in state k, for which the probability is $c(k;M,p)$. If he starts in state k, the probability that he will reach state 0 (observable action reversal) is $A(k,t,p)$. The second term conditions on the value state being bad, and consequently, the probability of observing a low signal is not p, but $1-p$.

[13]For example, suppose there have been 100 past actions, ending with the string $\emptyset AAAA$. We later prove that the first 95 actions are irrelevant (equal number of H's and L's); the abstention ($\emptyset$) indicates that the information in the first 96 signals cancels out. Only the last four A's are relevant for **N**. So this situation is equivalent to one where $N = 4$ and a string of 4 A's has occurred.

[14]In contrast with the binomial processes used in the financial option pricing literature, here the decision-maker's assessed probability of an L signal (down movement) is (signal-) state-dependent. The manager assesses a higher probability of an up movement after a previous up move because he reassesses the probability of the underlying value state.

2.5 Investment Choices with Partial Recall

Just after a transition, N with partial recall has an equivalent state that depends only on the past action history. Since the equivalent state must be an integer, for continuous calculations it is useful to define what we call the sub-equivalent state.

Definition *Let $\bar{e}$ be the equivalent state. A* sub-equivalent state *is defined as any real number on the interval $(\bar{e}-1, \bar{e}]$, if $\bar{e} > 0$, and on the interval $[\bar{e}, \bar{e}+1)$, if $\bar{e} < 0$.*

Thus, I's equivalent state, denoted $\bar{e}[M,p]$, is equal to the sub-equivalent state if the latter is an integer, and is equal to the next-larger-in-absolute-value integer if the latter has a fractional part. Using Bayes' rule (see Appendix A), we obtain:

Proposition 2 Partial Recall State

The new manager's sub-equivalent state can be expressed as

$$e[M,p] = 2 + \frac{\log\left[\frac{1-A(2,M-2,p)}{1-A(2,M-2,1-p)}\right]}{\log[p/(1-p)]}. \quad (2)$$

If the sub-equivalent state e is a fraction, it needs to be rounded up in absolute value, because an action *switch* does not occur until the absorbing boundary of 0 is crossed. For example, if the signal has precision $p = 2/3$, after observing six adopts N computes the sub-equivalent state to be $e(6, 2/3) = 3.23$, so the equivalent state is 4. Thus, he will reject the project after he observes exactly 4 L signals. By standard probability calculus, we obtain the probability of an action switch:

Proposition 3 Partial Recall Switch Probability

The probability that a new manager, having observed M successive adopt decisions, switches action within t periods after the manager shift is

$$r_{\mathbf{N}}(M,t,p) = Pr(G|M)A(\bar{e}[M,p],t,p) + Pr(B|M)A(\bar{e}[M,p],t,1-p). \quad (3)$$

The first term again conditions on the probability that the value state is good. A reversal is observed if $\bar{e}[M,p]$ low signals are observed (which happens with probability $A(\bar{e},t,p)$). If the value state is bad, the probability of a low signal is $1-p$ instead of p.

2.6 Transitional Inertia

We now compare the likelihood of action changes in the partial recall scenario with a change in managers to the full recall scenario where **I** remains in place. The relevant probabilities, as defined earlier, are $r_{\mathbf{I}}(M,t,p)$ and $r_{\mathbf{N}}(M,t,p)$. The next proposition shows that a firm with partial recall after a management change initially is inert (relative to a full recall firm):

Proposition 4 Transitional Inertia after Memory Loss
Conditional on M prior adopt decisions, a new manager never switches before time $M+\overline{e}(M,p)$ periods, whereas there is a strictly positive probability that a continuing manager switches by time $M+2$, where $\overline{e}(M,p)\geq 2$ for $M\geq 3$.[15]

This follows directly from equation (2) and (5) from Appendix A for $\overline{e}(\cdot)$ and $c(\cdot)$. Intuitively, after a sequence of M adopts by **I**, **N** does not know how strong the evidence was in favor of adopting. At best there could have been M consecutive H signals; at worst there could have been close to equal numbers of H and L signals. **N** will draw the statistical inference that quite likely the signal state is intermediate between these extremes. Thus, if M is sufficiently large, **N** believes it is unlikely **I** was very near the borderline, so he does not switch actions after observing just a single L signal. But a continuing **I** who has observed the actual sequence might have been right on the borderline. So if there was only very weak evidence supporting the current action, a continuing **I** will switch action based on one or only a few opposing signals with positive probability. Since N is more likely to switch than a continuing **I**, there is excess inertia. This intuition suggests that the result of transitional inertia is quite robust, and does not depend on the assumptions of a binary signal structure and value distribution.

To illustrate Proposition 4 numerically, with 10 prior adopts and a signal with accuracy of $p=0.51$, $\overline{e}(10,0.51)=5$. Within these five periods after the possible regime change, the probability that **I** switches is 15%, compared to 0% for **N**.

[15]For $M\leq 2$, **N** makes a perfect inference and consequently behaves like **I**.

2.7 Medium-Term and Long-Term Inertia

Does inertia persist beyond the first few decisions? We now describe conditions within our binary-signal model (but not for arbitrary distributions) under which this is the case. The comparison between scenarios with and without managerial replacement must be probabilistic, because sequences of signal realizations exist such that **N** switches when **I** does not, and *vice versa*.[16] We therefore compare the *probability* of an action switch over a given period of time for **N** versus **I**. Asymptotically, **N** exhibits excess inertia:

Proposition 5 Long-Run Inertia with Partial Recall
Holding constant the number $M > 3$ of immediately consecutive prior adoptions, as $t \rightarrow \infty$, the probability that the new manager reverses action at least once is less than or equal to the probability that the continuing manager does so. Holding constant the number $M > 3$ of periods before the switch,[17] as $t \rightarrow \infty$, the probability that the new manager reverses action at least once is strictly less than the probability that the continuing manager does so.

Proof: See Appendix B.

The intuition is as follows. If the firm begins with the wrong action, then with either full or partial recall (**I** or **N**), as information accumulates eventually there will be a switch to the right action. In this case there is no difference. Suppose instead that the firm begins with the right action. Then, under full recall, not infrequently the firm begins close to the decision boundary, and switches temporarily to the wrong action along the way. This is less common under partial recall since forgetting of past signals compresses **N**'s beliefs away from the edge of the decision boundary.

Even for an intermediate time period T after the switch, extensive simulations uniformly indicate that the probability that **N** switches is strictly below the probability that **I** switches for any $M \geq 3$. (For $M < 3$, **N** perfectly infers **I**'s information and so

[16] **N** may switch when a continuing **I** would have maintained, if **N** thinks that **I**'s signals were only moderately favorable to the old action, whereas the actual signal sequence strongly favored the old action. For example, suppose that **I** adopted three times based on sequence HHH. **N** thinks the sequence was either HHH or HHL. If **N** observes two further L's, he may abstain. **I** would not do so.

[17] Holding time constant, there could be any number of prior adopt decisions. Consequently, in some cases, both **N** and **I** will switch equally often; in other cases, the new manager will switch after **I**. Therefore the unconditional probability that **I** switches after **N** is positive.

behaves identically to a continuing I.) Thus, in the explored parameter ranges, the partial recall firm is inert. However, we are unable to prove this analytically in the medium term. Figures 1–4 plot some switch probabilities for the the two scenarios with different M (4, 32) and signal accuracies ($p = 0.5001, 0.6$).[18] The uniformly higher probability of switch under full recall illustrates inertia in the short, medium and long terms.

2.8 Strategic Project Choice

We have assumed so far that I maximizes expected profits each period. However, it may be better for the firm to sacrifice short-run profit to improve future decisions. If a managerial transition is foreseen, then I can, in the shareholders' interest, adjust his policies to communicate information to a later manager who does not have access to I's information signals. We call this behavior *strategic signaling.*[19]

To improve decisions, I and N could plan a "code" that translates I's signals into actions. One such code would require I to act in opposition to the preponderance of evidence right before the transition if he is sufficiently close to indifference.[20] The expected cost is low since deliberate incorrect decision-making is restricted to a few periods when the project is almost a toss-up. Thus, the benefit from strategic project choice sometimes outweighs the cost. However, in practice it may be difficult to design contracts that motivate a manager to select poor projects in order to signal information to his replacement (see the further discussion in Subsection 4.1).

[18]The firm under N is uniformly more inert when $M = 64$ or when $p = 0.51, 0.75$ or 0.9. All results have been both computed from the described formulas and confirmed in simulations (using the computed equivalent state decision rule).

[19]Another possible response is to discount heavily "strategic options" (followup investment opportunities) when deciding whether to undertake new projects; see Hirshleifer and Welch [1994].

[20]For example, an outgoing I who first observed 50 H signals and then 49 L signals would non-strategically adopt 99 times. To strategically signal, I could change his 99'th choice from adopt to abstain or reject despite the slightly favorable preponderance of evidence. This conveys the important information to N that there is not a *strong* preponderance of evidence in favor of the project (*e.g.*, 99 H's and 0 L's).

3 Two Extensions

Section 2 provided a setting in which old actions are very informative relative to new signals, which tends to lead to inertia. We show here two ways of extending the model so that old actions can sometimes carry relatively weak information: trinary signals (Subsection 3.1) and environmental change (Subsection 3.2). These extensions point to determinants of inertia versus the opposite behavior, *impulsiveness*, such as how recently old policies were established, and how rapidly the environment is changing.

With regard to the latter, even with full recall it is reasonable to place less weight on past signals if circumstances are changing. Environmental instability (stochastic shifts in the value of adoption) causes the value of information to decay, because information about the *past* value state becomes less relevant for the *current* adoption decision. The interesting point is that organizational amnesia *exaggerates* the relative weights placed on old versus new signals. In those cases in which, under full recall, the firm places heavy weight on the past (i.e., a stable environment), amnesia causes the firm to put even greater weight on the past (inertia). Conversely, in those cases in which under full recall the firm puts little weight on the past (i.e., a volatile environment), amnesia causes the firm to put even less weight on the past (impulsiveness).

Intuitively, with partial recall a firm cannot attune its policies perfectly to old information. A new manager observes only a coarse summary of what the previous manager knew, as reflected in past actions. If, on the whole, this summary is quite informative, then it makes sense to follow it often, and bear the cost of wrongly maintaining old policies when change is needed. This leads to excess inertia. If, on the whole, this summary is quite uninformative, then it makes sense to follow it seldom, and bear the cost of wrongly abandoning old policies when stasis is needed. This leads to excess impulsiveness. Thus, firms are rendered less inert (more impulsive) by factors that decrease the weight placed upon the initial manager's decisions.

3.1 Many Signal Values

Section 2 showed that the longer an action is established by **I**, the greater the inertia of N, but that even for recently established policies there was excess inertia. We show here that if signals are not binary, for policies established only a short period prior to memory loss, N may be impulsive. However, the general point that a longer tenure of past policies promotes inertia still applies. Even with non-binary signals, excess inertia obtains when past investment policies are long-standing.

To generate the simplest possible example, we now alter our basic model so that N cannot infer I's information after the first period. Specifically, we now assume that there are three possible signal values, H, M (no information), and L, and that the only actions possible are adopt and reject. (In this subsection M no longer refers to the number of pre-transition adopts.) When the manager is indifferent, he flips a fair coin to decide whether to adopt or reject. Consequently, N observing an adopt may suspect that I was indifferent (M).[21]

Table 4 Here

We assume a symmetric signal distribution (see Table 4) and two periods. In the partial recall scenario, I is replaced after the first period. Suppose that I adopted. N does not know whether I observed H, or observed M and flipped a coin. Thus, if N observes L, he *always* switches to reject. It follows that N always follows his own signal. In contrast, suppose that I stays in place. Now, if he observes L at date 2, he may not switch, because after the sequence HL he flips a coin to decide at date 2. This leads to the following result:[22]

Result 1: *When there are three signal values, a coin-flip indifference convention, and two dates, the partial recall firm is impulsive relative to a full recall firm.*

In this example, a single L signal is enough to outweigh the information conveyed by I's action. It can be shown that inertia returns in this modified model if there are many periods of adopting prior to the management transition. As in the basic model, the observation of several consecutive adopt decisions by I communicates fairly strongly that I has observed a preponderance of H over L (or M) signals. So the observation of just one or few L signals by N are not enough to switch action. In contrast, because

[21] Making M uninformative maintains the symmetry of the analysis. If the M signal were slightly informative, N would be impulsive even if I could "abstain" (which would then never be optimal in the first period). Thus, short-run impulsiveness is not an artifact of the coin-flip convention.

[22] The example can be strengthened by assuming that the date 2 signal (call it H_2 versus L_2) is slightly noisier than the date 1 signal (H_1 versus L_1). Then it is still the case that N always follows his own signal. In contrast, I only follows his own new signal if the first signal was M_1.

I may know that the preponderance of H over L was very weak, he may switch even when N would not do so. In summary, we expect inertia for long-standing investment policies (as in Section 2), and impulsiveness for recently enacted policies.[23]

3.2 Environmental Shifts

In a recent review and reassessment of theories of organizational memory, Walsh and Ungson (1991) suggest that organizational memory is crucial for effective response to environmental change. We show here that environmental volatility can lead to impulsiveness. Intuitively, N must decide whether to follow the policy indicated by the most recent information signal, or to stick to the old policy indicated more or less strongly by old information signals. Amnesia combined with environmental change can cause a loss in the value of lagged information such that one opposing signal outweighs the two lagged *actions*, but only sometimes outweighs lagged *signals*. Therefore, if the environment is appropriately volatile, transitional inertia (as in the basic model) gives way to transitional impulsiveness. (Of course, in either case amnesia leads to poorer tracking of environmental shifts.)

We continue to limit actions to either adopt or reject. Consider a setting as in the basic model with $M = 2$, but where, just before date 3, the underlying value of adopting versus rejecting may change. Specifically, with probability σ, the state is redrawn. If it is redrawn, with equal probability the new state is G or B. Thus,

$$Pr(\phi' = G|\phi = G) = 1 - \frac{\sigma}{2}.$$

Table 5 Here

We assume that the manager randomizes between adopt and reject (A and R) with equal probabilities when indifferent. We focus on the transitional behavior of N at date 3. Table 5 lists the possible behavior patterns in the example. N can perfectly infer the signal of I (thus acting alike in period 3) if I first adopts and then rejects (or vice versa). Thus, we concentrate on the case where I adopts or rejects for both periods.

[23]Since the results of the trinary model differ from the binary signal model of Section 2, it is of interest to consider what would happen if signals were continuous. We conjecture that similar conclusions would still apply, because the intuition discussed in the text does not seem to rely on signal discreteness.

The second column in Table 5 shows that if the probability that the underlying value is redrawn is sufficiently low, **N** is not impulsive. This is similar to the inertial outcome of Section 2. As the environmental volatility increases, a point is reached ($\sigma = \sigma_N$) where a single L signal outweighs the information implicit in two A's (which could have arisen from HH or HL). At this point, **N** always follows his own signal without regard to the past action, while a continuing **I** sometimes does not. Thus, the behavior of a partial recall firm is less stable than that of a full recall firm. Further increasing environmental volatility, an L signal not only outweighs two AA signals but also two HH signals, and both **I** and **N** follow their latest signals. This reasoning suggests the following result:

Result 2 In the model with frequent environmental shifts, the critical value for σ above which the firm always follows its date 3 signal is larger for the full recall firm than for the partial recall firm, $\sigma^N < \sigma^O$.

Proof: See Appendix C.

In the basic model, firms with long-standing policies are excessively inert (Proposition 4). This conclusion still obtains here if the environment is stable (σ low). In such an environment, memory improvements (*e.g.*, a better accounting system) that allow the firm to recall past signals will tend to weaken inertia and thereby encourage firms to react more quickly to external shifts.

In a more rapidly changing environment (medium σ), the relevance of old actions to current decisions is so weak that a partial recall firm always follows its new signal. Yet a full recall firm will sometimes follow its old signal. (The full recall firm is more willing to put some weight on the past because it knows past signals accurately instead of having to infer them from action.) Thus, **N** will tend to overreact to new information, and be too quick to reverse old policies. In such an environment, memory improvements (*e.g.*, a better accounting system) will tend to make the firm *more* willing to retain old policies.

Finally, for a highly unstable environment (high σ) even a full-recall firm will follows the new signal, because the past information is simply not relevant enough to outweigh recent information. In this case **I** or **N** will behave the same, and there is neither excess inertia nor impulsiveness.

Thus, if the policy has only been in place briefly when the managerial transition occurs (as in the preceding subsection), or if the environment changes with intermediate rapidity, impulsiveness rather than inertia may obtain. Most industries probably change gradually enough that the relevant problem is inertia, but such rapidly-changing industries as computing and telecommunications may display impulsiveness.[24] This is especially the case when employee job mobility (and loss of firm-specific memory) is high, *e.g.*, as in Silicon Valley during the rise of personal computing.

4 Value and Sources of Institutional Memory

4.1 Information Storage, Transmission and Retrieval

The inefficiencies just described can be eliminated if I accurately records the signal state and communicates it to N. Thus, our model is most applicable for policies for which information is hard to record, store, retrieve, and transmit. Keeping poor records is sometimes optimal, owing to the costs of storing and accessing information about many small decisions. This suggests that the more important the decision, the better the record-keeping. However, a second reason for poor record-keeping is the need for confidentiality. This may be greater for important decisions than for minor ones. A third reason for poor record-keeping is that some decisions are unforeseen, so a recording system is not planned. In summary, our theory suggests that problems resulting from amnesia should be relatively more important for decisions a firm makes, for decisions that depend on confidential information, and for decisions that were not obviously foreseeable. Fourth, there may be agency problems wherein managers have an incentive to misrepresent information in a self-serving way.[25] Thus, stored information may not be credible. Also, it may be hard to motivate a manager to exert effort to preserve information when the benefit to the firm will be realized only after he has departed.

[24]Thus, Henry Ford's view that "History is more or less bunk... We don't want tradition... the only history that is worth a tinker's damn is the history we make today," is more appropriate to the Ford of 1916 than the Ford of today.

[25]Stored information may affect his reputation or the motivation of employees to work hard. For example, a manager may want others to believe that a project he initiated is of high quality.

4.2 Executive Mobility and Succession

Some organizational theorists have emphasized the disruptive effects of managerial succession (e.g., Grusky [1960]). Consistent with this view, there is evidence that the announcement of voluntary CEO departures without pressure by the board is on average associated with negative abnormal stock returns (Furtado [1989]). Two trends suggest that the problems that arise from memory loss may be of growing importance: the increasing tendency of large U.S. firms to hire outsider CEO's, from 9% in the late 1960's to 27% in the 1980's (Vancil [1987]), and the movement toward elimination of middle-management levels through downsizing.

Our theory implies that firms whose managers are more mobile, retire earlier, and are hired from the outside have more severe problems of inertia and impulsiveness than firms that provide lifetime employment, have late retirement age, and in which new management is groomed for the job. In the aggregate, our model suggests that the common assertion that greater employee mobility in the U.S. translates into a more flexible economy needs to be refined. While mobility allows firms to adjust labor usage easily, it may cause undesirable memory loss and lead to inertia or impulsiveness in decision-making. Factors that might seem to help entrench the status quo—low turnover, promotion from within, and late retirement ages—can sometimes improve the firm's ability to adapt.

Owing to the high turnover rate of programmers, "reverse engineering" the software developed by departed programmers is a growing problem (Peterson [1993]). Although it is easy to communicate the actions of individual programs (or major subroutines) to a new programmer, it is often extremely difficult to understand the detailed rationale for specific pieces of code. A new programmer is likely to be more reluctant than the original programmer to make major changes in the code.[26] This effect can lock a firm into an unwieldy information system.

Management style also influences organizational memory. Consensus management techniques presumably distributes memory about reasons for decisions (not just the

[26]Subroutines and lines of code can have hidden rationales and side effects that make them difficult for a later programmer to understand. Indeed, the movement first to procedural languages and now to object-oriented programming encourages modularization to reduce the need to make *any* changes to old code.

decisions themselves) among more participants. This reduces the memory loss associated with turnover, at the cost of the time and effort required to achieve consensus. Similarly, the benefits of functional specialization within a management team must be balanced against the memory loss when a key member departs.

Firm size also affects memory. In large firms memory of decision rationales is spread among many managers. This suggests that large firms have a relatively steady rate of forgetting associated with a steady turnover proportion. In contrast, small firms are likely to have poor memory in periods when an executive leaves, but good memory when no turnover occurs. So an entrepeneurial firm should usually be more agile than bureaucracies with steady turnover, but occasionally suffer severe memory losses (leading to inertia or impulsiveness as optimal but imperfect responses).

Record-keeping can also be related to firm size, because there can be scale economies in remembering. A large firm can afford to incur the fixed costs of institutionalizing memory by computerizing, introducing sophisticated internal accounting systems, and supporting redundant managers.[27] This suggests that sometimes big firms can be *nimbler* than small firms in reacting to change.

Turnover should impose lower amnesia costs on large than on small firms, owing both to steadier proportionate turnover and scale economies in information management systems. Our analysis therefore suggests that large firms optimally should adopt policies more conducive to employee turnover. Grusky (1961) finds that large firms do indeed have higher rates of turnover.[28]

Corporate boards of directors can be useful as reservoirs of memory when top executives are replaced. This provides a rationale for a strong insider presence on the board. However, for this purpose insiders need not be *voting* members. Since boards preserve memory only imperfectly, the notorious reluctance of directors to remove poorly

[27]The text discussion focuses on preservation of signals. The greater use of formal procedures and routines of large firms may help them preserve implicit memory of past actions. This point is consistent with the view of Grusky (1961) that the greater bureaucratization of large firms makes them less adversely affected by managerial succession.

[28]To examine these hypotheses empirically, a researcher must be careful of a post-selection bias. Small firms that suffer a drastic memory loss may often go out of business. There is thus a tendency to compare lumbering large firms with up-and-coming competitors, which biases results in favor of the conventional conclusion that small firms are generally more nimble and adept at tracking environmental shifts than large firms.

performing CEOs can be viewed as excess inertia. Our analysis implies that in volatile environments, impulsiveness is possible. This suggests that in contrast to the entrenchment of large corporate managers, entrepeneurs financed by venture capitalists may be removed *more* often than would be optimal under full recall.

4.3 The Value of Institutional Memory

Firms can use a variety of costly means of improving institutional memory. The extent to which they do so depends on the value of full recall (rather than partial recall of actions but not signals). Consider a firm that faces repeated environmental shifts, and has repeated memory losses about past signals.

If the probability of a value shift is quite low, then the past history of actions becomes highly informative about the value state.[29] Fairly accurate decisions can therefore be made even without recall of signals, so the value of full recall is relatively low. If volatility is quite high, past history of any sort has little relevance for the future, so there is again little gain to preserving past signals.[30]

Thus, the value of full recall is greatest for firms with intermediate environmental volatility. This suggests a relation between the typical life cycle of a firm and its inertia. During the initial phase (an upstart venture) volatility is high, and will tend to diminish as the business matures. Thus, the hump-shaped pattern in the value of memory in relation to volatility implies that very mature businesses and upstart ventures will invest the least in memory systems, and that firms in businesses with intermediate maturity will invest the most. For these intermediate businesses we expect to see greater computerization, greater groupware usage, highly-developed management accounting systems, long managerial tenure, high pay, promotion from within rather than hiring from without, and insider membership on boards of directors.

This suggests several empirical implications. Startup firms should begin with relatively lower levels of the memory-enhancing characteristics listed above. As the firm grows and uncertainty is resolved about how it fits its environment, it should invest rel-

[29] The history of actions will not become *fully* informative, because of informational cascades (see the literature discussion in Subsection 5.2). However, it will carry considerable useful information.

[30] The general trend (cited earlier) among U.S. firms toward hiring outsider CEO's since the 1960's could, in part, be related to a more volatile business environment as markets have globalized.

atively more in memory-enhancement. At a considerably later stage when the business is thoroughly routine, the firm may cut back on these costly memory mechanisms. Empirically, outsider succession has been found to be more frequent in younger companies and in faster-growing industries (Helmich [1975], Helmich and Brown [1972]).

Some firms in long-term decline seem to be locked into continuing poor policies. When things go badly for a firm, executives and employees are tempted to depart. Such departures carry away memory, which causes the firm to do even worse. Our approach suggests that this effect will lead to mistakes that accelerate the collapse of distressed firms. Hambrick and D'Aveni (1992) found in a sample of distressed firms rapid and accelerating divergences in managerial team characteristics (such as team size, average managerial tenure in the firm, and functional expertise mix) between failing firms and matched survivors in the years preceding bankruptcy. These variables are possible memory proxies (other interpretations are also possible). The authors state that "The results thus suggest that deterioration of the top management team is a central element of the downward spiral of large corporate failures."

The analysis also suggests that preservation of memory may be important for government policy issues such as the optimal term lengths and limits for legislators and other officials. Memory preservation provides one rationale for a civil service in which a newly elected executive cannot replace bureaucrats at will. It also provides a reason to re-elect incumbents ("Don't change horses in mid-stream"). Our theory suggests that the incumbency advantage and the desirability of long tenure for officials is greatest when the environment is very stable.

5 Policies, Routines, Traditions, and Culture

5.1 Traditions, Rules, and Taboos

Even without explicit sanctions, traditions and conventions have great influence upon behavior.[31] Progressives and radicals have often argued that traditional norms and rules are irrational. In their view, people should select the best policies based on the

[31] Weick and Gilfillan (1971) provide experimental evidence that arbitrary traditions of group behavior sometimes persist as group composition gradually changes, without explicit sanctions or externalities.

latest information about current circumstances, rather than deferring to the dead hand of the past. The same criticism can be leveled at organizational routines.

Amnesia provides a rationale for rules and traditions. Traditions reflect the hard-won experience of previous generations. If we do not possess all the information known to our predecessors, then it can be optimal to adhere to traditional behavior. In this spirit, Friedrich von Hayek (1967, chapters 4 and 6) has argued that there is a wisdom in the spontaneous order of traditions and rules that may not be evident to current decision-makers. As expressed vividly by G.K. Chesterton (1908; ch. 4):

> Tradition may be defined as an extension of the franchise. Tradition means giving votes to the most obscure of all classes, our ancestors. It is the democracy of the dead. Tradition refuses to submit to the small and arrogant oligarchy of those who merely happen to be walking about. All democrats object to men being disqualified by accident of birth; tradition objects to their being disqualified by the accident of death. Democracy tells us not to neglect a good man's opinion, even if he is our groom; tradition asks us not to neglect a good man's opinion, even if he is our father.

While social amnesia makes it rational to stick with traditions and rules, such traditions are not without cost. Tradition only summarizes useful information from the past. Actual preservation of detailed information is better, because then people will know when to *break* with tradition. Therefore, our theory is consistent with the fact that traditions have tended to be supplanted more frequently as *better* mechanisms for information preservation were invented (*e.g.*, Gutenberg's printing press or textual data bases).

Our analysis implies that in volatile environments, excess impulsiveness rather than inertia can obtain. Thus, environmental instability makes individuals more receptive to new behaviors. This idea is a recurring theme of the social philosopher Eric Hoffer, who observed that "...a population subjected to drastic change is a population of misfits—unbalanced, explosive, and hungry for action."[32] Our analysis is consistent with

[32]See Hoffer [1964], Ch. 1). Hoffer (1971, ch. 9) also argues that "We used to think that revolution is the cause of change. Actually it is the other way around: revolution is a by-product of change. Change comes first, and it is the difficulties and irritations inherent in change which set the stage for revolution."

Hoffer's view. However, he argues that changes in behavior results from the *emotional* discomfort of living an a changed environment. The motivation for new behavior we emphasize is weakened belief in the profitability of conventional behaviors in a changing environment.

Rituals and taboos are specific types of traditions that seem to lack current justification from an outsider's perspective. According to Freud (1950), "Taboo prohibitions have no grounds and are of unknown origin. Though they are unintelligible to *us*, to those who are dominated by them they are taken as a matter of course" [p. 18], and "No external threat of punishment is required, for there is an internal certainty, a moral conviction, that any violation will lead to intolerable disaster" [p. 26-7]. One explanation for the persistence of taboos is that people suspect a good rationale exists, though forgotten or preserved only in the form of crude allegories.[33]

5.2 Alternative Theories

As mentioned in the introduction, there has been little formal study of impulsiveness (oversensitivity to new information). However, there are numerous theories of inertia and related behaviors; see Kuran (1988) for a review of theories of conservatism, and Rumelt (1994) for theories of organizational inertia. In this subsection we contrast several alternative theories with our own. It is likely that actual behavior is influenced by a combination of factors.

One possible source of inertia is managerial irrationality. Several of the theories summarized by Rumelt (1994) are of this kind; see also Thaler (1980). Our analysis implies that in some cases inertia can occur even if individual managers are fully rational.[34]

The organizational ecology literature generally assumes that firms do not change, and focuses on how populations of firms are modified through processes of creation and selection. Hannan and Freeman [1984] justify this assumption based on the need for reliability. Institutionalization of procedures leads to reproducible outcomes but reduced

[33]McNeil (1976) pp. 155-56 discusses seemingly irrational folkways, probably arrived at by trial and error, which in the light of modern medical science are recognized as protecting against deadly disease.

[34]The limited ability of individuals to broadcast or absorb information (implicit in a failure of institutional memory) should be distinguished from an invalid use of information that the individual has ample opportunity to absorb (as in theories of irrational inertia).

flexibility. This contrasts with an adaptionist perspective which emphasizes change in individual organizations in response to the environment (see, e.g., Nelson and Winter [1982]). Our theory provides an alternative explanation for a *degree* of inertia, but still implies that organizations adjust to their environments.

Kuran (1987) provides a model in which individuals inherently prefer to, or feel social pressure to conform, leading to periods of stability interrupted by occasional large shifts. In contrast, inertia in our paper is purely informational.

Dixit (1992) discusses an options theory of inertia based upon the benefit of deferring costly changes until further information arrives. Dixit's theory implies that inertia is strongest in a highly volatile environment. In our theory, volatile environmental change *opposes* inertia and can lead to its opposite, impulsiveness.

A recent literature on informational cascades also derives inertia as a consequence of the statistical inference by later decision-makers about the signals observed by early decision-makers (see Banerjee [1992], Bikhchandani, Hirshleifer and Welch [1992], and Welch [1992]). In these models, cascades-induced inertia occurs after a sufficiently large number of individuals have made decisions, and cascading individuals follow predecessors with certainty. In the model presented here, inertia or impulsiveness develops after the *multiple* decisions of a *single* decision-maker. Also, we examine here the more general outcome where there is a *probability* that the manager will follow past actions.

Some theories of inertia are based on divergence of interests between different decision-makers (see e.g., Rasmusen [1992]). For example, a manager may take actions in order to persuade observers that he has high ability (see Kanodia *et al* [1989], Boot [1992], Prendergast and Stole [1993], and Zwiebel [1995]). Our analysis is based on information loss rather than divergent interests.

5.3 Distinguishing Alternative Theories

Our theory predicts both under what conditions we would observe inertia versus impulsiveness, and the instrumental variables related thereto (*e.g.*, managerial mobility, managerial overlap, information storage systems). Managerial mobility variables can be measured directly, or with measures of firm-specific human capital. Other theories with the same or opposite implications suggest other instrumental variables. For example, several alternative theories predict that managers associated with old projects should be more attached to them, implying inertia. Our model implies that this is not necessarily the case; in the basic model, managerial *turnover* implies excess inertia.[35]

Second, the analysis provides implications about which firms should find investment in retaining organizational memory most valuable (see Subsection 4.3). This yields predictions about firms' life-cycle pattern for adopting the memory-enhancing mechanisms listed earlier.

A plausible alternative view of turnover is that new managers are hired specifically to bring about policy changes. An empiricist could use the form of managerial turnover (*e.g.*, retirements or death versus firing) to distinguish different effects. Reputational agency theories in which incumbents are "wedded" to their projects suggests stronger effects when the manager is far from retirement. The opposing volatility prediction of Dixit's strategic option theory of inertia was mentioned earlier. And our theory has the distinct implication that the adoption of computing and management information systems may be an important determinant of inertia versus impulsiveness. Since alternative theories provide good instrumental variables, it would be interesting to design a test to distinguish different effects.

The introduction of "Groupware" programs at many firms is providing natural experiments on the effects of changes in organizational memory. These programs facilitate the recording and retrieval of transactions and decisions within the firm. If effective, groupware should help improve memory and therefore rectify problems of inertia and impulsiveness.[36] Our analysis therefore predicts that groupware will reduce inertia for firms in stable industries, but move firms in more volatile environments toward *greater* inertia (less impulsiveness).

[35]Duhaime and Grant (1984) find only weak (statistically insignificant) support for their hypothesis that managers of divested units had low managerial "attachment" to (past responsibility for) their divisions.

[36]The importance of these issues is highlighted by IBM's recent $3.3 billion acquisition of Lotus in order to acquire Lotus' Notes software.

6 Summary and Extensions

6.1 Summary

How information retention affects organizational policies is of growing importance as modern economies shift to services and information management, and as restructuring cause managerial and employee turnover. This paper has examined the effects of organizational memory loss, arising from turnover or from failures in accounting and information systems, communication, and individual memory. The model is based on the premise that new managers can observe/recall the firm's previous *actions* but are unaware of the *rationale* for these actions.

We find that if the environment is stable, and if a firm has followed an old policy a long enough time, there is *excess inertia*: as new information arrives the firm tends to maintain old policies more under partial recall (e.g., a new manager) than with full recall (e.g., a continuing initial manager). Thus, the model implies that organizational routines and cultural norms that institutionalize inertia should be more extensive and effective in stable environments than volatile ones. Under the opposite set of circumstances, i.e., when the value of old information is weak and/or decays over time, there is *excess impulsiveness*: the partial recall firm will tend to shift policies more often than would a full recall firm. Thus, the model implies that the frequency of policy changes (*e.g.*, reversal of project choices) is determined by such factors as managerial and employee turnover, the quality of record-keeping and information systems, how long the project or activity has been in place, and the volatility of the firm's environment.

The possibility of excess inertia of a new manager may seem surprising, because management transitions are often associated with policy changes. As mentioned earlier, there are good reasons outside our model for management turnover to be associated with policy change. Without minimizing the importance of such fairly obvious effects, we emphasize a countervailing pressure that has not previously been recognized, as well as providing additional implications relating to other sources of memory loss (imperfect communication, accounting and information systems).

Since recall and decision-making are costly, it can pay to institutionalize decisions through organizational routines or cultural norms. Thus, our approach views routines a way of institutionalizing beneficial inertia. Our approach can help explain when and why such routines are desirable. More broadly, our approach provides an explanation for social impulsiveness or inertia, as reflected in the strength or weakness of traditions, conventions, rituals and taboos.

6.2 Extensions

A manager can more easily observe the actions of a competing firm than the underlying information signals. Thus, the implications of our analysis for inertia versus impulsiveness can also be applied to predict when firms will conform to or deviate from the actions of other firms. For example, under conditions leading to inertia, our model implies that a new entrant may adhere to an initial firm's policies more consistently than the initial firm itself. However, in a cross-firm context, the factors determining "memory" are different. Inertia and impulsiveness can be avoided not by improved internal memory systems, but by better monitoring the competitor (e.g., by hiring away some of the competitor's managers, or by espionage). Also, the analog to the environmental change in the intra-firm theory of Subsection 3.2 is cross-firm heterogeneity.

In our model, the initial and replacement managers have identical information quality. We conjecture that the higher the precision of the replacement manager relative to the initial manager, the greater the impulsiveness of the new manager. Higher relative precision should cause the new manager to place more weight on his most recent signals rather than on observation of past actions. Thus, we predict greater inertia when the new manager is an outsider entering an industry requiring deep specialized knowledge (as in the Gerstner/IBM example mentioned near the start of the text). Also, our analysis helps explain the common view that a new manager should be given a "breathing period" before being seriously evaluated. In those circumstances where he will optimally be inert, there is little to judge.

We see at least three directions for further research related to the model:

(1) The Architecture of Organizations

Sah and Stiglitz have described in a series of papers (reviewed in Stiglitz [1989]) how the architecture of organizations (*i.e.*, the structure of decision hierarchies) affects how well organizations utilize information to make decisions. Owing to imperfect information flows, mid-level managers may place either insufficient or undue weight upon the recommendations of subordinates. This leads to possible inertia or impulsiveness, and the need to design an organizational architecture to counteract these problems.[37]

(2) Individual Memory

While there has been some effort by economists to incorporate findings from psychology to understand economic decisions (see, *e.g.*, Akerlof and Dickens [1982] and much of the recent literature on behavioral economics), economists have seldom attempted to apply economic reasoning to explain psychological mechanisms. In the current article, we have stressed that organizations can forget even if individuals have perfect memories. However, forgetting has interesting consequences for individual behavior as well. In work in progress, we are examining the relation between forgetting and effects resembling cognitive dissonance, "loyalty filters" (see Akerlof [1983]), progression toward extremist behavior, and the "*status quo bias*" identified in psychological experiments. We believe such an approach may provide an analytical foundation for self-perception (or attribution) theory (Bem [1965]), in which people inferentially attribute reasons or motives to themselves based upon observation/recall of their own actions and experiences.

(3) Inertia and Impulsiveness in Macro-Equilibrium

We have modelled the influence of the environment on the organizational policies. It would be interesting to model the feedback from the behavior of many organizations upon the business environment. Our finding that environmental stability promotes inertia and instability promotes impulsiveness suggests that self-reinforcing effects can occur. A slight shift toward volatility in the environment may cause firms' policies to become more impulsive, making the environment even less stable. Thus, economy-wide shifts in the degree of policy stability may often seem disproportionate to the cause.

[37] Khanna and Slezak (1995) compare the efficiency of information flows in teams versus hierarchies in a setting that excludes impulsiveness. Some recent authors have examined how, for reputational reasons, managers may tailor their reports to try to match the priors of their superiors or the market (Brandenberger and Polak [1995], Prendergast [1993]).

Appendices

For notational simplicity, in all the appendices we will take as given that the most recent past actions were adoptions. The analysis is symmetric for past rejections, so this is without loss of generality.

Appendix A: The Basic Model

Payoff Structure

The net gains each period from adopting or rejecting the current project are summarized in Table 3. The net discounted value of the project is unknown, either $v = 1$ (G value state) or $v = -1$ (B value state), equally probable and unknown to the managers. These are the payoffs obtained by adopting (undertaking the project). Rejecting the project yields a payoff of 0 in both states. Abstaining from decision generates net payoffs of $0.5 + \epsilon$ or $-0.5 + \epsilon$ ($\epsilon > 0$ small) in states G and B respectively, which are halfway between that from adopting and rejecting (plus ϵ). With ϵ small, the manager abstains if and only if he is (arbitrarily close to) indifferent between adopting and rejecting.

Table 3 Here

Preliminary Lemmas

The probability that **I**'s action changes is the likelihood of reaching signal-state $s_t = 0$. The following two well-known lemmas about Markov processes are used in subsequent analysis. Let θ be the probability of an up move. For notational simplicity, we focus on the case of $s_0 > 0$.

Lemma 1 *Starting at position $s_0 > 0$, the probability of reaching state $s_t = 0$* **exactly once** *at (and not before) time t is*

$$a(s_0, t, \theta) = \begin{cases} 0 & \text{if } t < s_0, \text{ or } s_0 + t \text{ is odd} \\ \frac{s_0}{t} \begin{pmatrix} t \\ \frac{t+s_0}{2} \end{pmatrix} \theta^{(t-s_0)/2} (1-\theta)^{(t+s_0)/2} & \text{otherwise.} \end{cases}$$

Lemma 2 *Starting at position $s_0 > 0$, the probability of reaching state $s_t = 0$* **at least once** *("absorption") by time t is*

$$A(s_0,t,\theta)=\begin{cases}0 & \textit{if } t<s_0\\ A(s_0,t-1,\theta) & \textit{if } t+s_0 \textit{ is odd, and } t\geq s_0\\ B\left(\frac{t-s_0}{2},t,\theta\right)+\left(\frac{1-\theta}{\theta}\right)^{s_0}B\left(\frac{t-s_0}{2}-1,t,1-\theta\right) & \textit{otherwise,}\end{cases}$$

where $B(\cdot)$ is the cumulative binomial distribution,

$$B\left(k,t,\theta\right)=\sum_{i=0}^{k}\begin{pmatrix}t\\ i\end{pmatrix}\theta^i(1-\theta)^{t-i}.$$

The recursion implicit in the middle entry of $A()$ must "bottom out" since moving backwards from and odd value for $t+s_0$ must lead to an even value.

Deriving The Probability that the State is Good

Given a sequence of M adopt decisions, the probability that the value state is G is

$$Pr(G|M,p)=\frac{Pr(M|G)Pr(G)}{Pr(M|G)Pr(G)+Pr(M|B)Pr(B)}.$$

We can use lemmas 1 and 2 to compute $Pr(M|G)$ and $Pr(M|B)$. Any qualifying signal sequence must lead at the start to 2 adopts, and thus must start with two H signals. Then, starting at signal state 2, it must be followed by a signal sequence that does not touch state $s=0$ (observable abstention) within $M-2$ periods. Thus,

$$\begin{aligned}Pr(M|G,p) &= p^2[1-A(2,M-2,p)].\\ Pr(M|B,p) &= (1-p)^2[1-A(2,M-2,1-p)],\end{aligned}$$

and $Pr(G|M,p)$ becomes

$$Pr(G|M,p)=\frac{p^2[1-A(2,M-2,p)]}{p^2[1-A(2,M-2,p)]+(1-p)^2[1-A(2,M-2,1-p)]}. \quad (4)$$

Proof of Proposition 1: Choices of I

Because I knows the lagged signals, his optimal decision is based on the difference in the number of H and L-signals. The probability of an action *switch* by time t is the probability that the number of L-signals equals the number of H-signals by time t. In Markov terms, this happens when the particle reaches the (absorbing) boundary 0. In Proposition 1, we define

$$c(k;M,p)=\frac{a(k,M,1-p)}{p^2(1-A[2,M-2,p])}\quad (k\leq M). \quad (5)$$

$r_{\text{inc}}(M,t,p)$ consists of the probability $A(k,t,p)$ of starting at state k and not being absorbed within t periods (reaching 0 and thus abstaining), weighted by the probability $c(k;M,p)$ of starting out in state k given the observed M adopt decisions, in turn weighted by the probability that the value state is either good (G) or bad (B).

We now verify that $c(k;M,p)$ is the conditional probability of starting in state k, given M prior adopts. We first compute the posterior probability of a manager being in state k given M adopts if the probability of an H signal is p (*i.e.*, assuming for the moment that the value state is G).

The numerator of equation (5) gives the probability of being in state k and having M prior adopts. The denominator normalizes the probabilities. It exploits the fact that $\sum_k a(k,M,1-p) = p^2(1 - A[2, M-2, p])$, because the first two signals must be H, and no absorption may take place within the remaining $M-2$ periods. □

Proof of Proposition 2: Investment Choices of N

A manager whose equivalent state has higher absolute value is less likely to switch his action at least once within a given time period than a manager in an absolutely lower state.[38] A very useful property of this system is that the manager can base his decision solely on the signals or actions that he observes since the last abstain decision. Thus, prior to the change in managers, the relevant summary of past actions is just the number of immediately preceding consecutive all-adopt (or all-reject) decisions. We therefore need only show that, starting with an arbitrary number M of all-adopt decisions, **N** has a lower probability of switching than **I** within an arbitrary t periods after the switch.

Let $\mathcal{I}$ be the information set the manager has about events prior to the date of possible manager change. Let $\mathcal{N}$ be the signal sequence received by the manager after the managerial transition. By Bayes' rule, the decision rule for a manager is abstain if

$$E(V|\mathcal{I},\mathcal{N}) \equiv \frac{Pr(\mathcal{N}|G)Pr(\mathcal{I}|G)}{Pr(\mathcal{N}|G)Pr(\mathcal{I}|G) + Pr(\mathcal{N}|B)Pr(\mathcal{I}|B)} = 1/2,$$

reject if the expectation is less than 1/2, and adopt in the reverse case. Simplifying this

[38]Proof: the set of possible signal realizations that lead the manager in a higher state to switch is a subset of the set of possible signal realizations that lead the manager in a lower state to switch.

expression, the condition for abstaining becomes

$$Pr(\mathcal{N}|G)Pr(\mathcal{I}|G) = Pr(\mathcal{N}|B)Pr(\mathcal{I}|B).$$

Let k be the equivalent state, *i.e.*, the extra number of L-signals over and above any H-signals that are required to bring a manager who has observed $\mathcal{I}$ back to indifference (or beyond). In our Markov structure, $Pr(\mathcal{N}|G) = (1-p)^k$ and $Pr(\mathcal{N}|B) = p^k$, so

$$(1-p)^k Pr(\mathcal{I}|G) = p^k Pr(\mathcal{I}|B), \quad \text{or}$$

$$k = \frac{\log[Pr(\mathcal{I}|G)/Pr(\mathcal{I}|B)]}{\log[p/(1-p)]}. \tag{6}$$

Noninteger solutions for k give sub-equivalent states.

As expected, adding one more H signal to $\mathcal{I}$ increases k by 1 regardless of the information in $\mathcal{I}$.[39] Thus, a manager can act by computing his state (or state inference) based on the last abstain decision—when I was publicly known to be in state 0.[40]

Finally, we need to compute $Pr(\mathcal{I}|G)$ and $Pr(\mathcal{I}|B)$. This has already been used in the computation of $Pr(G|M)$. It is the probability of all sequences that lead to uniform adopt decisions, *i.e.* that start with two H-signals, and are followed by sequences that do not lead to absorption within $M-2$ periods. Therefore, the sub-equivalent state for N who has observed successive M adopt decisions by I (and no signals of his own) is as given in Proposition 2.

Appendix B: Proof of Proposition 5[41]

We begin with two lemmas.

Lemma 3 *The sub-equivalent state* e *and the probability* π *that the value state is* G *are related by*

$$e = \frac{\log[\pi/(1-\pi)]}{\log[p/(1-p)]}. \tag{7}$$

[39] After one additional H signal, $Pr(\mathcal{I}|G)$ is replaced by $Pr(\mathcal{I}|G)p$; $Pr(\mathcal{I}|B)$ by $Pr(\mathcal{I}|B)(1-p)$.

[40] The (sub-)equivalent state is *not* the expected state. Suppose, for example, that the expected state is greater than 5. It is easy to provide a numerical example (6 prior adopts, $p = .9$) in which the equivalent state is only 4, *i.e.*, four low signals suffice to induce N to reverse course. The reason is that an additional L signal cause the manager to revise his inference about past signals in favor of L over H. (I.e., since the manager observes only pretransition actions, not signals, he has low confidence in the estimate of state implied by his information about pretransition behavior.)

[41] This proof was pointed out to us by Larry Glosten.

Proof: Let π_e be the probability that the value state is G given the sub-equivalent state expression given above. (It is easy to show that there is a one-to-one map between the two.) Taking the odds ratio of π and assuming that $Pr(G) = Pr(B)$, we find that

$$\frac{\pi_e}{1-\pi_e} = \frac{Pr(G|e)}{Pr(B|e)} = \frac{Pr(e|G)}{Pr(e|B)} .$$

Because the sub-equivalent state is defined in equation (6) as

$$e = \frac{\log[Pr(e|G)/Pr(e|B)]}{\log[p/(1-p)]} ,$$

it follows that

$$\frac{\pi_e}{1-\pi_e} = \left(\frac{p}{1-p}\right)^e .$$

Solving for e, we find (7).□

We can now state the probability of obtaining a reversal given that the manager starts at sub-equivalent state e as a probability of obtaining a reversal given that the value state is G. Let C denote the event that no reversal is ever observed, and C' be the complementary event that reversal is observed.

Lemma 4 *The cumulative asymptotic probability of ever observing a reversal given an arbitrary number of past adoptions is related to the probability (π_e) that the value state is G:*

$$Pr(C'|e) = 2 - 2\,\pi_e . \tag{8}$$

Proof: Because the probability of observing a reversal as $T \to \infty$ if I took the wrong action is 1, the probability of C is the probability that the action is correct given the (unknown) value state (so that there is a drift away from zero) times the probability of (temporarily) not reaching a state of 0. Consequently, the probability of no reversal given sub-equivalent state e is

$$Pr(C|e) = \pi_e \left[1 - \left(\frac{1-p}{p}\right)^e\right] ,$$

where π_e is the (above) probability that the value state is good given starting state e. Using the relation between π_e and e in (7), we can substitute for e and use the fact that $x^{a \log(y)} = y^{a \log(x)}$ to obtain

$$Pr(C|e) = \pi_e \left[1 - \left(\frac{1-p}{p}\right)^{\frac{\log(\pi_e/(1-\pi_e))}{\log(p/(1-p))}}\right] = \pi_e \left[1 - \left(\frac{1-\pi_e}{\pi_e}\right)^{\frac{\log([1-p]/p)}{\log(p/(1-p))}}\right] = 2\pi_e - 1\,.$$

□

Proof of Proposition 5:

I: I's reversal behavior is computed by the modeller as the weighted sum of reversal probabilities:

$$Pr_{\text{inc}}(C|A^M) = \sum_{s=1}^{M} Pr(C|s)Pr(s|A^M)\,.$$

Using (8) from lemma 4, this expression can be simplified to

$$\sum_{s=1}^{M}(2\pi_i - 1)\; Pr(s|A^M) = \sum_{s=1}^{M}\left[2\,Pr(G|s)\,Pr(s|A^M) - Pr(s|A^M)\right] = 2\,\hat{\pi}_M - 1\,,$$

where $\hat{\pi}_M$ is the probability that the value state is G given M pre-transition adopts.

New Manager: N starts at the next-highest integer ($\overline{e}$) following the sub-equivalent state e as in (7). Consequently, the equivalent state $\overline{e}$ is the sum of the sub-equivalent state e and and a positive fraction ($0 \leq f < 1$). Using equation (8),

$$Pr_{\text{new}}(C|\overline{e}) = \pi_e\left[1 - \left(\frac{1-p}{p}\right)^{\overline{e}}\right] = \pi_e\left[1 - \left(\frac{1-p}{p}\right)^{e+f}\right] = \pi_e\left[1 - \left(\frac{1-p}{p}\right)^{e}\left(\frac{1-p}{p}\right)^{f}\right]$$

$$= \pi_e\left[1 - \left(\frac{1-\pi_e}{\pi_e}\right)\left(\frac{1-p}{p}\right)^{f}\right] = (2\pi_e - 1) + (1-\pi_e)\left[1 - \left(\frac{1-p}{p}\right)^{f}\right], \quad (9)$$

which is greater than $2\pi_e - 1$ when $f > 0$.□

Appendix C: Proof of Result 2

This appendix proves that $\sigma^N < \sigma^O$, so that the region of excess impulsiveness of the amnesiac firm actually does exist. A verbal outline of the reasoning follows. At the end of period 2, the difference between H and L signals after HH or LL is 2 or -2. For the amnesiac firm, the sub-equivalent state after AA or RR is less than 2 in absolute value, because the second action may have been the result of a coin flip. By the definition of σ^N, the amnesiac firm is virtually indifferent after AA followed by L (or RR followed by H). HH is more favorable than AA, so it follows that the full-recall firm strongly prefers to follow the old signals after HH (or LL). We will need two lemmas.

Lemma 5 *Let G' denote the event $\phi' = G$. Then $Pr(G'|G,L) > Pr(G'|B,L)$.*

Intuitively, conditioning on G rather than B state increases the probability that the later state is G'. The algebraic details are routine, so the proof is omitted.

Lemma 6 $Pr(G|HHL) > Pr(G|AAL)$.

Intuitively, conditioning on HH is more favorable than conditioning on AA, which may or may not have come from HH. The routine algebraic details are omitted.

Proof of Result 2: We wish to show that there exists values of $\sigma \in [0,1)$ such that

$$Pr(G'|AAL) < \frac{1}{2} < Pr(G'|HHL).$$

Expanding the LHS and RHS terms gives

$$\begin{aligned} Pr(G'|AAL) &= Pr(G'|AAL,G)Pr(G|AAL) + Pr(G'|AAL,B)Pr(B|AAL) \\ Pr(G'|HHL) &= Pr(G'|HHL,G)Pr(G|HHL) + Pr(G'|HHL,B)Pr(B|HHL). \end{aligned}$$

So

$$\begin{aligned} Pr(G'|AAL) &= Pr(G'|L,G)Pr(G|AAL) + Pr(G'|L,B)[1 - Pr(G|AAL)] \\ &= [Pr(G'|L,G) - Pr(G'|L,B)]Pr(G|AAL) + Pr(G'|L,B), \end{aligned}$$

and

$$\begin{aligned} Pr(G'|HHL) &= Pr(G'|L,G)Pr(G|HHL) + Pr(G'|L,B)[1 - Pr(G|HHL)] \\ &= [Pr(G'|L,G) - Pr(G'|L,B)]Pr(G|HHL) + Pr(G'|L,B). \end{aligned}$$

In order to show that $Pr(G'|AAL) < Pr(G'|HHL)$, it is sufficient to show that

$$\begin{aligned} Pr(G'|G,L) &> Pr(G'|B,L) \\ Pr(G'|HHL) &> Pr(G'|AAL). \end{aligned}$$

These are true by Lemmas 5 and 6.

Consider now some σ arbitrarily close to zero. Then

$$\begin{aligned} Pr(G'|HHL) &\approx Pr(G|HHL) \\ &= \frac{Pr(HHL|G)Pr(G)}{Pr(HHL|G)Pr(G) + Pr(HHL|B)Pr(B)} \\ &= p. \end{aligned}$$

So for $p > 1/2$ and $\sigma > 0$ small, the continuing **I** will always adopt after HHL. On the other hand, if $\sigma \approx 1$, then history is irrelevant, so the **I** will always reject.

Similarly, consider σ close to 1. Then

$$\begin{aligned} Pr(G'|AAL) &\approx Pr(G'|L) \\ &= \frac{Pr(L|G')Pr(G')}{Pr(L|G')Pr(G') + Pr(L|B')Pr(B')} \\ &= 1 - p. \end{aligned}$$

So for $p > 1/2$ and $\sigma \approx 1$, **N** always rejects after AAL.

If $\sigma \approx 0$, then the probability that the state is G given observation of AAL is

$$\begin{aligned} Pr(G'|AAL) &\approx \frac{Pr(G, AAL)}{Pr(AAL)} \\ &= \frac{\frac{1}{2}[Pr(HHL|G) + \frac{1}{2}Pr(HLL|G)]}{\frac{1}{2}[Pr(HHL|G) + \frac{1}{2}Pr(HLL|G)] + \frac{1}{2}[Pr(HHL|B) + \frac{1}{2}Pr(HLL|B)]} \\ &= \frac{1+p}{3}. \end{aligned}$$

So if $p > 1/2$, **N** always accepts after AAL.

To summarize, as σ increases from 0 to 1, both $Pr(G'|AAL)$ and $Pr(G'|HHL)$, decrease from greater than 1/2 to less than 1/2. Since $Pr(G'|AAL) < Pr(G'|HHL)$ for all $\sigma \in [0, 1)$, it follows by continuity of these probabilities in σ that for all $p > 1/2$ there exists a value of $\sigma \in [0, 1)$ such that $Pr(G'|AAL) < 1/2$ and $Pr(G'|HHL) > 1/2$. Thus, for some σ **N** rejects after AAL while **I** accepts after HHL. □

Table 1: **Conditional Signal Distribution Probabilities: Basic Model**

Signal Value	**Value State** G	B
H	p	$1-p$
L	$1-p$	p

Table 2: **Signals and Actions in 4-Period Example**

First 3 Periods		All 4 Periods						
I Observes	I Chooses	Signal t=4	Info Set I	Decision	Info Set N	Decision	Info Set Identical	Decision Identical
LLL	RRR	L	LLLL	R	RRRL	R	N	Y
LLL	RRR	H	LLLH	R	RRRH	R	N	Y
LLH	RRR	L	LLHL	R	RRRL	R	N	Y
LLH	RRR	H	LLHH	[∅]	RRRH	[R]	N	[N]
LHL	R∅R	L	LHLL	R	R∅RL	R	Y	Y
LHL	R∅R	H	LHLH	∅	R∅RH	∅	Y	Y
LHH	R∅A	L	LHHL	∅	R∅AL	∅	Y	Y
LHH	R∅A	H	LHHH	A	R∅AH	A	Y	Y
HLL	A∅R	L	HLLL	R	A∅RL	R	Y	Y
HLL	A∅R	H	HLLH	∅	A∅RH	∅	Y	Y
HLH	A∅A	L	HLHL	∅	A∅AL	∅	Y	Y
HLH	A∅A	H	HLHH	A	A∅AH	A	Y	Y
HHL	AAA	L	HHLL	[∅]	AAAL	[A]	N	[N]
HHL	AAA	H	HHLH	A	AAAH	A	N	Y
HHH	AAA	L	HHHL	A	AAAL	A	N	Y
HHH	AAA	H	HHHH	A	AAAH	A	N	Y

Description: H is a "high" signal, increasing the probability that the underlying state is G ("good") rather than B ("bad"). L is a "low" signal, decreasing the probability that the underlying state is G. A denotes a decision to adopt (optimal when G is more likely than B), R a decision to reject (optimal when G is less likely than B), $\emptyset$ a decision to abstain (optimal when G and B are equally likely). Signals and optimal decisions are listed in order of time period. For example, LHL means that an L signal was received in period 1, H in period 2, L in period 3. A new manager is assumed to observe only actions, not signals. The table shows that if the signals LLH or HHL occur, **N** behaves more inertly than a continuing **I**.

Table 3: **Payoffs**

Action		**Value State** G	B
Adopt	A	1	-1
Reject	R	0	0
Abstain	$\emptyset$	$\epsilon + 1/2$	$\epsilon - 1/2$

Table 4: **Conditional Signal Distribution Probabilities: Trinary Case**

Signal Value	**Value State** G	B
H	p	$1 - p - q$
M	q	q
L	$1 - p - q$	p

Table 5: **Firm Behavior with Partial or Full Recall in a Shifting Environment**

	Low σ ($\sigma < \sigma^N$)	**Medium** σ ($\sigma^N < \sigma < \sigma^O$)	**High** σ ($\sigma^O < \sigma$)
Partial Recall	Follow matched pre-transition action.	Follow latest signal.	Follow latest signal.
Full Recall	Follow matched pre-transition signal.	Follow matched pre-transition signal.	Follow latest signal.

Figure 1: Lagged Adopts (M). Signal Accuracy (p) of 0.5001

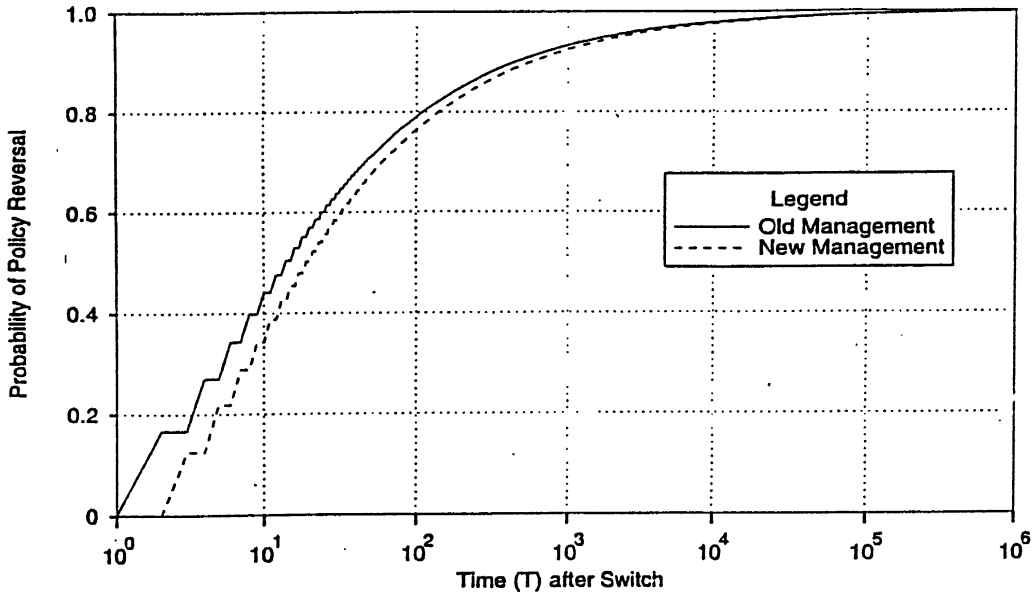


Figure 2: Lagged Adopts (M) Signal Accuracy (p) of 0.5001

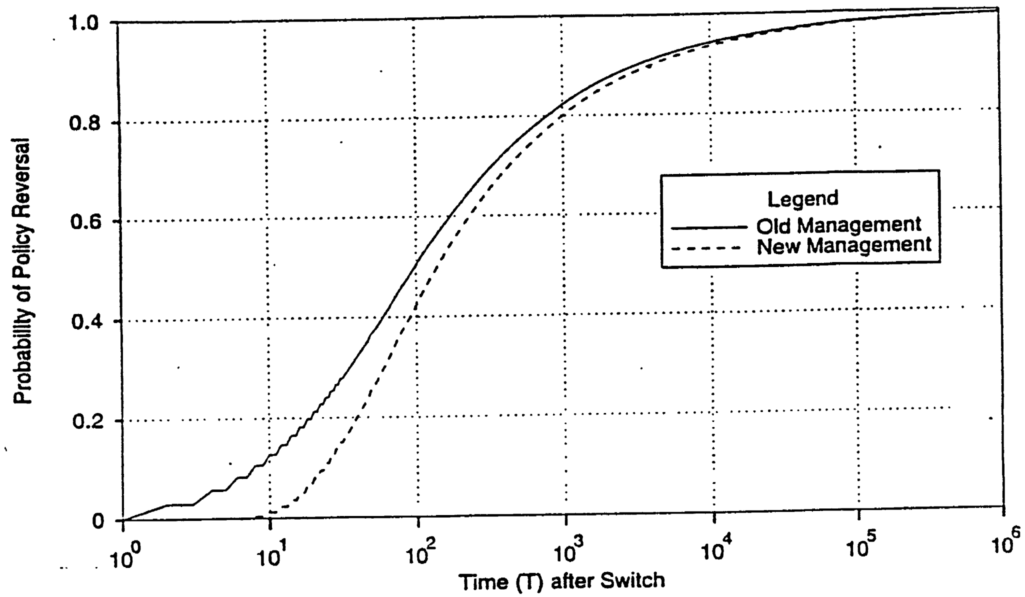


Figure 3: Lagged Adopts (M). Signal Accuracy (p) of 0.5001

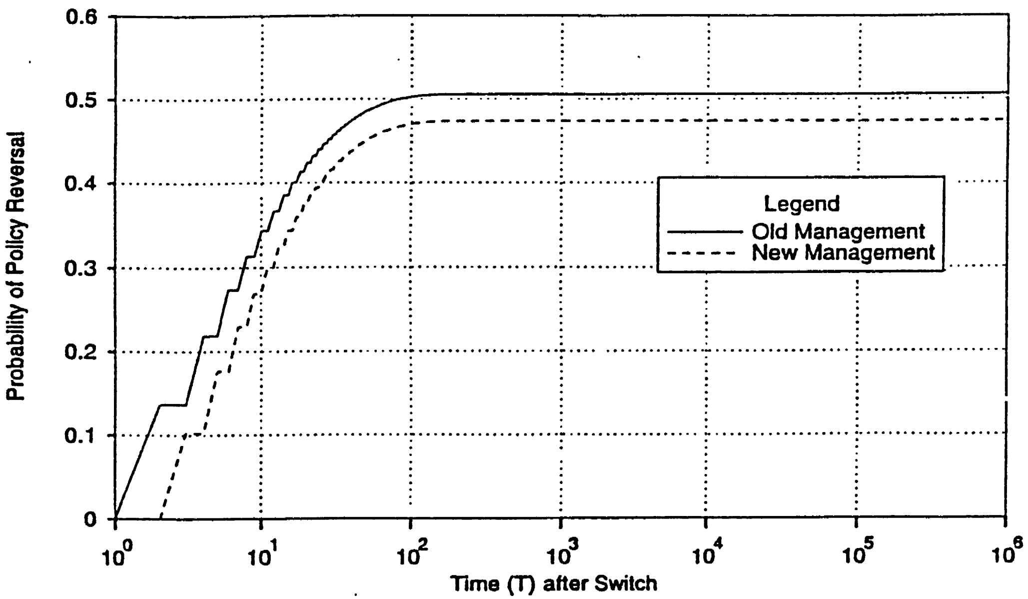
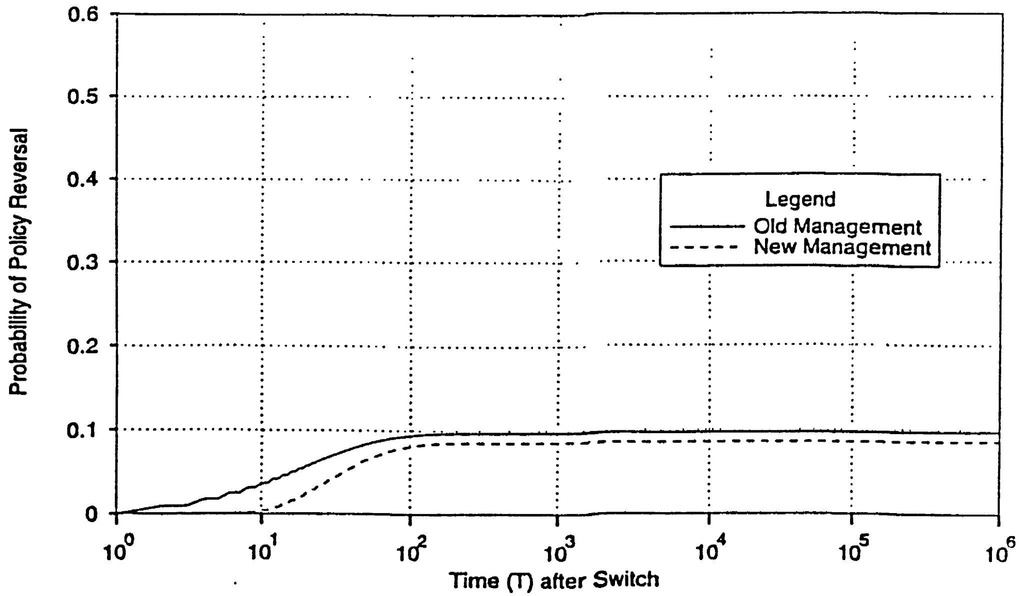


Figure 4: Lagged Adopts (M) Signal Accuracy (p) of 0.5001



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