Online supplement to:

MEMORY AND ORGANIZATIONAL EVOLVABILITY IN A NEUTRAL LANDSCAPE

Amit Jain
Assistant Professor
D-ETM and the Department of Strategy and Policy
National University of Singapore
Faculty of Engineering
Block E2, #05-10
7 Engineering Drive 1
Singapore 117574
Tel: (+65) 6516 1638
Fax: (+65) 6776 0755
E-mail: amit_jain@nus.edu.sg

Bruce Kogut
Sanford C. Bernstein & Co. Professor of Leadership and Ethics
Columbia Business School
3022 Broadway, Uris Hall 706
New York, NY 10027
Tel: (+1) 212- 854-9050
Fax: (+1) 212-854-0016
E-mail: bruce.kogut@columbia.edu

CONTENTS

Robustness tests: Costs in Space and over Time

The simulations presented in the paper took into consideration time by discounting the future by calculating net present values. If evolution is guided by Nature with infinite patience, the discount rate is essentially zero. However, organizations care about time and the inter-temporal tradeoff between exploitation today and exploratory benefits tomorrow. We now develop further the mechanics of memory by investigating whether its effect on evolvability is robust to time and costly change.

Robustness over discount rates and costs per move

We begin by testing for robustness of our baseline parameters. Since our simulation analysis of value used fixed parameter values (i.e. an annual discount rate of 5 percent (0.43 percent per month/time period) and search costs of 0.5 units per time period), we first verify that the above results are not unduly an artifact of the parameter values selected. To this end, we computed the NPV ratio of a population searching with memory (Q4) to another searching without memory (Q3), using our baseline NK parameters (neutrality = 0.10. K=4), for discount rates ranging from 0.43 to 25 percent per month, and for normalized search costs ranging from 0 to 0.6.

Table 1 Robustness: Memory and neutrality enable evolvability over a broad range of search costs and discount rates (Neutrality = 0.1, K=4)

	Discount rates (percent)					
Cost per move	**0.43**	**1**	**2.5**	**5**	**10**	**25**
0.0	1.00	1.00	1.00	1.01	1.01	1.00
0.1	1.07	1.07	1.07	1.06	1.05	1.02
0.2	1.16	1.16	1.15	1.13	1.10	1.04
0.3	1.26	1.26	1.25	1.22	1.16	1.01
0.4	1.38	1.39	1.37	1.33	1.26	1.11
0.5	1.54	1.54	1.53	1.49	1.39	1.19
0.6	1.73	1.75	1.75	1.72	1.62	1.38

The value creating property of memory is robust over a broad range of search costs and discount rates. In the table, we compute the NPV ratio as a ratio of the average NPV created by population of organizations searching with memory to that of another population without memory. The NPV ratio is greater than one over all parameter values.

The results shown in table 1 indicate that as search costs increase, the NPV ratio of memory to no memory increases. Memory leads to efficient search and as the cost of inefficiency (search costs) rises, the contribution of memory to value created increases. The NPV ratio decreases as discount rates increase. This decline indicates the gains to memory are more pronounced in the future, showing that evolvability pertains to the long-run.

The results of these tests reinforce the central intuition of our analysis that "*the tradeoffs of inertia and learning by experience inherent in memory tips towards evolvability when the value of time is added to the analysis.*" As seen in table 1, when search costs are equal to 0.5 per move, the NPV ratio with a discount rate of 1 percent is 1.54 and this falls to 1.19 when the discount rate is 25 percent. These numerical results indicate that the evolvability of memory is robust over a broad range of search costs and discount rates.

Costs of using memory

As a second check on robustness, we consider now the effects of adding costs to the use of memory. Reverting to a prior organizational configuration in memory can be costly. For instance, if a firm introduces piece rates and assembly lines into its production processes and later realizes that they are incompatible, then it would want to revert to prior practices. However, reverting to prior practice is not easy and comes at some cost, a cost not taken into consideration in our analysis to this point. To this end, we introduced a cost of using memory to check whether the contribution of memory to evolvability remains robust. Each time an organization starts search from a position in memory when stuck in a competency trap, it incurs a cost of using memory ranging from 0 (no cost) to 5 (ten times the cost of search in a period).

We computed NPV ratio as the ratio of the NPV of a population searching with memory to another population with no memory. The results presented in table 2 show that the NPV ratio decreases as the cost of using memory increases. However, even when the cost of memory is 5 (equal to ten adaptive/neutral moves in a time period), search with memory leads to an NPV ratio greater than 1 over a

broad range of neutrality values. These results show that the evolvability of organizations is enhanced in the presence of neutral search and memory even when accessing memory is costly.

Table 2. Robustness. Memory and neutrality enable evolvability when there are high costs of using memory

	Cost of using memory				
Neutrality	0	0.5	1	2.5	5
0.000	1.02	1.02	1.01	1.01	1.01
0.020	1.13	1.12	1.12	1.12	1.12
0.040	1.24	1.24	1.24	1.24	1.23
0.067	1.39	1.39	1.38	1.38	1.37
0.100	1.54	1.53	1.52	1.51	1.48
0.125	1.38	1.35	1.32	1.23	1.07

Memory leads to a positive NPV even when there is a cost of using it. The table provides the NPV ratio of a population searching with memory to another without it, where neutrality ranges from 0 (adaptive search) to 0.125, and the cost of using memory ranges from 0 to 5 (compared to a cost of search of 0.5). We take K=4, search cost = 0.5, and a annual discount rate of 5 percent (0.43 percent per month/simulation time period). Even when the cost of using memory is 5, that is, ten times the cost of search in a time period, memory leads to a positive NPV ratio over a range of neutrality values.

All in all, our analysis suggests that memory enhances change in organizations in neutral landscapes. Neutral search permits organizations to find ridges between hills and thereby to escape from competency traps; however, organizations take a long time to find their way through neutral pathways, and then into a better prototypical category. Memory improves on this random neutral drift, since the organization now remembers the paths it took before and does not needlessly duplicate prior mistakes. This value of memory is robust to different cost and discount rates (table 1).