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Electronic Companion—"Patterned Interactions in Complex Systems: Implications for Exploration" by Jan W. Rivkin and Nicolaj Siggelkow, *Management Science* 2007, 53(7) 1068–1085.

Online Appendices

Appendix 1. Visualizations of Performance Landscapes

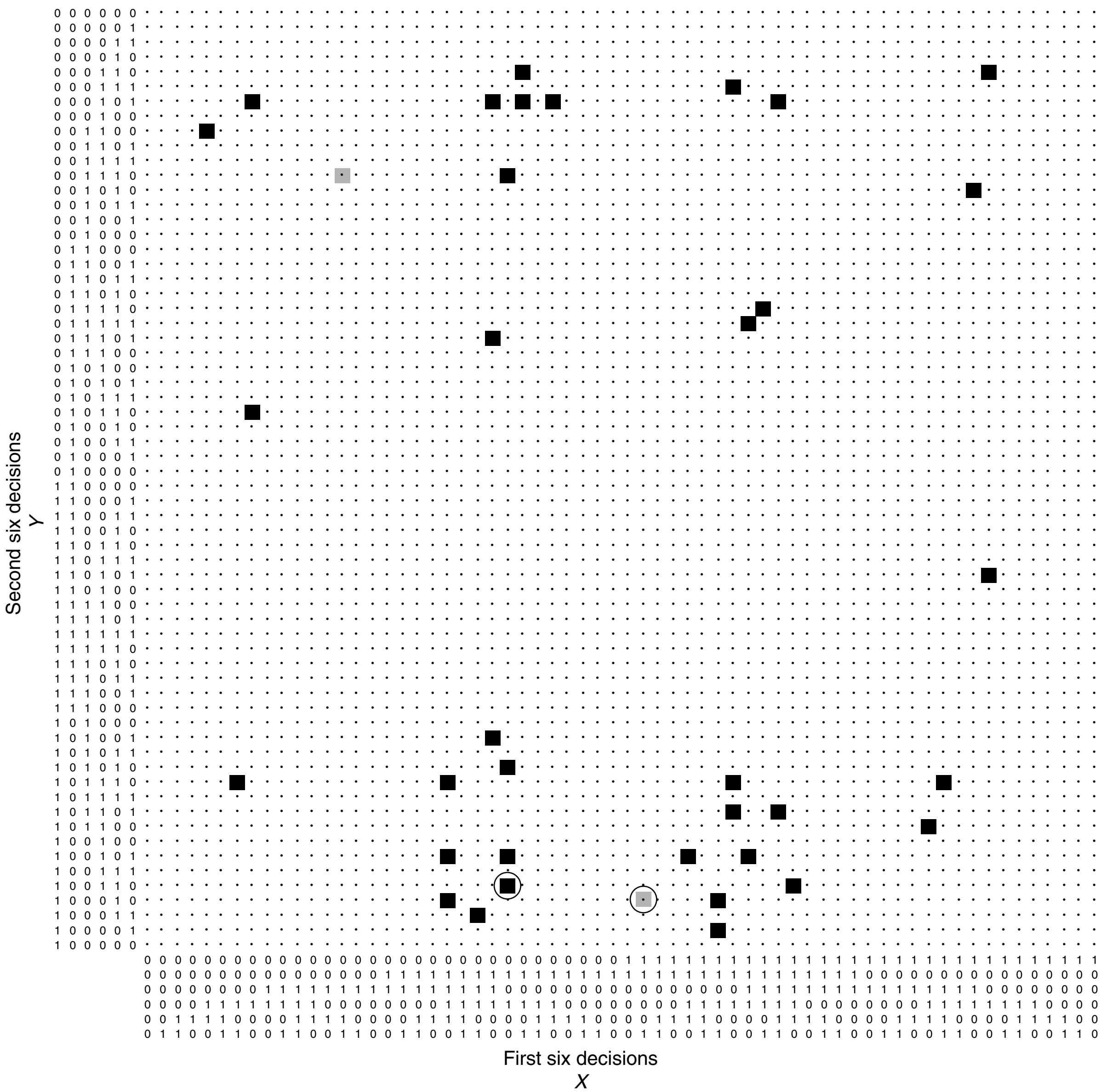
To depict a 13-dimensional space (12 choice dimensions and one resulting performance dimension) in three dimensions (on a two-dimensional sheet of paper) is obviously not a straightforward matter. We choose a representation that preserves a good amount of localness. In particular, we place the $2^{12} = 4{,}096$ underlying choice configurations of the landscape on a $64 * 64$ array so that points that are direct neighbors on the x- or y-axis are choice configurations that differ in only one choice, i.e., are local neighbors in the 12-dimensional space as well. Moreover, we choose an arrangement of points that highlights the structure of the centralized landscape with pronounced ridges and plateaus, as described in §5 of the main paper. Figure EC.1 shows the particular arrangement of choice configurations. The first six choices of each configuration are given by the six-digit strings of zeroes and ones depicted along the x-axis; the second six choices are given by the strings depicted along the y-axis. For instance, the choice configuration in the lower left corner is 000000100000. The points immediately to its right and immediately above it are, respectively, 000001100000 and 000000100001—two points that differ in exactly one decision from 000001000000. While a certain degree of localness is preserved by this representation, one should note that points that are not adjacent to each other are not necessarily more than one decision apart from each other. (Given that each choice configuration has 12 local neighbors, this is the inevitable price one pays for depicting 12 dimensions in two dimensions.) As a result, a number of points might look like local peaks, yet they are actually not because neighbors with higher performance do not appear right next to them on the depiction.

To show two very different landscapes, we focus on one landscape generated by a centralized influence matrix and one produced by a dependent matrix. (As Table 3 of the main paper shows, the centralized and dependent matrices produce the least and most local peaks, respectively, on average.) In particular, we choose $K = 1$. In this case, for the centralized structure, the first decision affects all other decisions; the second decision affects the first decision and itself; and each other decision affects only itself. Thus, we expect that changes in decision 1 will lead to the largest performance changes in the landscape, changes in decision 2 will lead to the second-largest changes, and all other areas of the landscape will be relatively flat plateaus. To show this structure, we arranged the choice configurations so that all choice configurations that have the first decision set to zero are on the left half of the x-axis (the first 32 columns), and all choice configurations that have the first decision set to one are on the right half of the x-axis (the last 32 columns) (see Figure EC.1). Thus, for the centralized structure we would expect a large ridge right over the middle of the x-axis. Likewise, decision 2 changes two times (at 1/4 and 3/4 of the way along the axis), and again we would expect ridges at these positions.

Figure EC.2, which depicts a sample landscape with an underlying centralized interaction pattern, indeed shows these features. The landscape is pictured so that the x-axis lies in front. The landscape shows a major cliffside directly in the middle of the x-axis, right where the first decision switches from zero to one. Likewise, ridges appear at 1/4 and 3/4 of the x-axis, where decision 2 switches. The other areas display a plateau-like characteristic; note in particular the right portion of the landscape, where neither decision 1 nor 2 changes. This specific sample landscape actually has two local peaks. The locations of these peaks are marked by the two gray squares in Figure EC.1. The global peak has a circle around it.

Figure EC.3 depicts a sample landscape generated with a dependent interaction pattern. Even keeping in mind the caveat that true local peaks are not easily spotted in the low-dimensional depiction,

Figure EC.1 Landscape Grid and Locations of Local Peaks in Two Sample Landscapes



Notes. Grey squares represent the two local peaks in a sample landscape with a centralized interaction matrix. Black squares represent the 35 local peaks in a sample landscape with a dependent interaction matrix. Circles around squares denote the global peaks in either landscape.

this landscape shows a much more rugged surface than the landscape based on the centralized pattern. Indeed, this sample landscape has 35 local peaks, whose locations are indicated by the black squares in Figure EC.1. (The global peak is again denoted by a circle around a square.) Note that the local peaks tend to be clustered in "mountain ranges," as discussed in the main text.

Appendix 2. Broader Exploration Generated by Different Organizational Structure

Prior research efforts—both empirical classics like Burns and Stalker (1961) and kindred simulations like Rivkin and Siggelkow (2003)—have shown that organizational designs differ in how much exploration they encourage. Thus, broader exploration can be generated not only by broadening the range of alternatives that managers can evaluate—the mechanism emphasized in §6—but also through a change in organizational design.

Specifically, we focus on two stylized organizational structures: a *decentralized* structure that allows for broad exploration but lacks coordination, and a *hierarchical* structure that can coordinate but

Figure EC.2 Centralized Landscape with $N = 12$ and $K = 1$

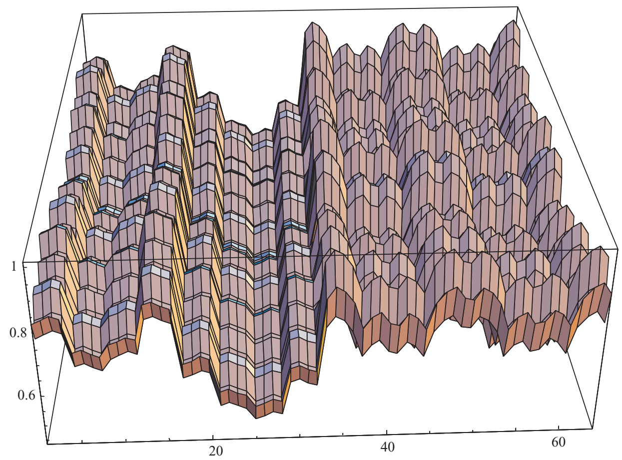
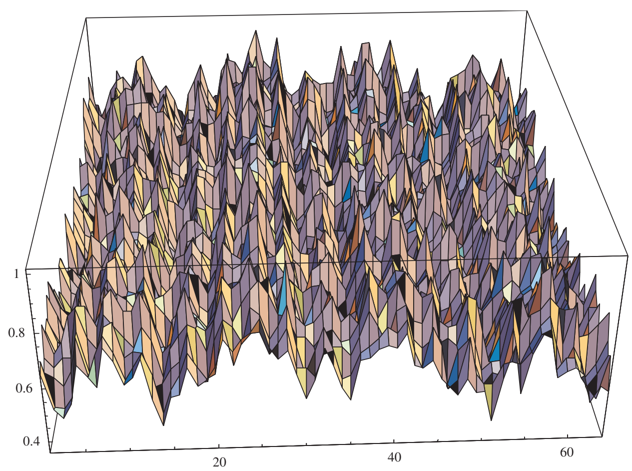


Figure EC.3 Dependent Landscape with $N = 12$ and $K = 1$



restricts exploration. Specifically, in the *decentralized firm*, decisions are split between two managers, A and B. Manager A is responsible for the first $N/2$ decisions, while Manager B is responsible for the remaining $N/2$ decisions. In each period, each manager evaluates two local (search radius $= 1$) alternatives for her department and implements the alternative (or the status quo) that yields the highest performance for her department (but not necessarily for the firm as a whole). In the *hierarchical firm*, decisions are again split up and department managers assess alternatives as in the decentralized firm. In this firm, however, each department manager is required to send her most preferred alternative to a CEO. The CEO, in turn, evaluates all possible combinations of departmental proposals and implements the combination that is best for the firm.

We place one decentralized and one hierarchical firm on a random starting point on each landscape, measure the performance of firms at the end of Period 300 and, in Table EC.1, report the average performance differences between the decentralized firm and the hierarchical firm. Each data point is an average over 1,000 landscapes of each type. A positive difference denotes that the decentralized firm outperforms the hierarchical firm; a negative difference implies that the hierarchical firm has the higher performance.

The column labeled "random" replicates the finding of Rivkin and Siggelkow (2003), who used random influence matrices. For low levels of K, the hierarchical firm significantly outperforms the decentralized firm, while for high levels of K, the decentralized firm significantly outperforms the hierarchical firm. Similar trends in the performance differences arise in all columns: as K increases, the benefit of the decentralized structure increases. These trends reflect the impact of organizational design

Table EC.1 Performance Advantage of the Decentralized Firm

	Centralized	Hierarchical	Scale-free	Random	Preferential attachment	Local	Block-diagonal	Diagonal	Dependent
$K=1$	−0.0007	0.0006	−0.0016	**−0.0076**	*−0.0057*	−0.0032	−0.0012	0.0007	**0.0173**
$K=2$	−0.0011	0.0045	*0.0065*	*−0.0070*	*−0.0058*	−0.0014	−0.0007	*0.0053*	**0.0321**
$K=3$	0.0058	0.0000	0.0054	−0.0059	0.0019	0.0039	−0.0000	**0.0099**	**0.0362**
$K=4$	0.0000	0.0043	*0.0070*	0.0022	*0.0070*	0.0049	−0.0001	**0.0131**	**0.0409**
$K=5$	0.0027	**0.0207**	*0.0080*	*0.0089*	*0.0066*	*0.0065*	0.0023	**0.0169**	**0.0464**
$K=6$	0.0012			**0.0134**	**0.0101**	**0.0144**	0.0010		**0.0419**

Notes. Each cell contains the performance difference in Period 300 between a firm that is decentralized and a firm that employs a hierarchy. Performance is measured relative to the highest performance possible on each landscape. Performance differences are averages over 1,000 landscapes. Differences in italics are significant at a level of 0.05; differences in bold are significant at a level of 0.01.

on exploration: The autonomy of departmental managers in the decentralized firm permits broad exploration, while in a hierarchical firm, the oversight of a CEO—who refuses to ratify moves that reduce performance even temporarily—confines exploration. As K increases and local peaks proliferate, broad exploration becomes more valuable on the margin, and the benefit of the widely exploring decentralized design increases.

The interesting new finding is in the rows. For $K=2$, for instance, the hierarchical structure leads to significantly higher performance than the decentralized structure when the underlying interaction structure is random (difference $= -0.0070$), but the performance ranking between these two firms reverses when the underlying interaction structure is dependent (difference $= +0.0321$). This result is consistent with the prior intuition: For the same level of K, landscapes with dependent interaction structures have many more local peaks than landscapes with random interaction structures, so we would expect the benefit of the broader exploration generated by the decentralized structure to arise at lower levels of K when the firm is on a dependent landscape than when the firm is on a random landscape.

In sum, the comparative static results with respect to K—in this case, "the performance of the decentralized structure relative to the hierarchical structure increases with K"—continue to hold regardless of the underlying interaction pattern. At the same time, results at particular values of K can change depending on the interaction pattern.

References

See references list in the main paper.