Cognitive Systems RESEARCH

Endogenous disjoint change

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Abstract

Traditionally, models of macro-political change, like those of macro-economics, have been based on extremely unrealistic assumptions about human cognition, ranging from fully informed and rational to completely random. Following from the work of Herbert Simon and contemporaries, a new tradition has developed based on more realistic ideas of human cognition. This paper lays out the need for such models in understanding endogenously produced disjointed change in public policies. It documents the commonality of such changes at the macro-level and points to the contributions of many recent works in developing realistic models of human cognition providing the basis of a new and more fruitful literature.
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1. Introduction

Traditionally, those concerned with the behaviors of social systems have been satisfied with "as-if" models of the behaviors of individuals whose actions generate the behavior of the system. In the tradition of classical economics, markets behave "as if" consumers were fully informed and rational (see Friedman, 1953; Simon, 1957 for a discussion). In the garbage can theory of organizational choice (see Cohen, March, & Olsen, 1972), individual decision-makers make their choices randomly. Clearly, neither school is concerned with "getting it right" at the individual level. Rather, they seek to understand the dynamics at the system-level, and rough assumptions about the micro-behavior of individuals are often "good enough"

to drive useful models at the aggregate level. Or so it has been thought.

Bryan Jones raises the question of whether we may be on the verge of developments in various scientific disciplines that may allow us to use more realistic models of individual human reasoning and decision-making to understand systems. In the field of public policy, typically we want to understand how the system works. But wouldn't it be nice if we could do so using models of individual behavior that make sense? Assuming away virtually all that we know about individual cognition and decision-making (individuals are perfectly rational; individuals make choices randomly) may make for interesting parlor-games, or it may demonstrate the power of aggregation, but it cannot be satisfying as a model of human behavior. The question is, what are the prospects for understanding the behavior of complex systems such as those that generate public policy in modern governmental institutions based on relatively realistic models of individual cognition? The articles

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included in this special issue can be understood in that light.

2. Individual cognition and collective outcomes

Bryan Jones notes (2017) that we can distinguish between the behavioral sciences, with extensive focus on the behaviors of individuals, and the social sciences, which are more concerned with the functioning of systems. Economics is typically understood as a social science and psychology a behavioral one; political science and sociology are mixed. Public policy and public administration are clearly on the social side. Cognitive science, of course, is fully behavioral. Jones notes that the key insights making possible any combination of reasonable individual cognitive assumptions were made in and around 1959 by Herbert Simon and his associates. Simon wanted to understand how public administrations make decisions and felt he could not do so unless he based his models on how individuals within those administrations made decisions. Hence the idea of bounded rationality, satisficing, and, crucially, the idea of "canalizing" decisions: working in parallel streams, multi-tasking for a time until decisions must be made by a central authority. Scarcity of attention, at the individual or the organizational level, is key. This raises the question of whether we can understand disjoint change in organizations with reference to endogenous factors. The answer to that question then determines whether one's model of disjoint policy change must refer to stochastic shocks or exogenous events. If canalizing decisions into separate streams is a fundamental characteristic of collective decision-making within institutions, occasionally these separate channels must come together. Analyzing this process, fundamental to the issue of agenda-scarcity, allows us to think of a solution to an important puzzle. Let me explain the puzzle with a simple example.
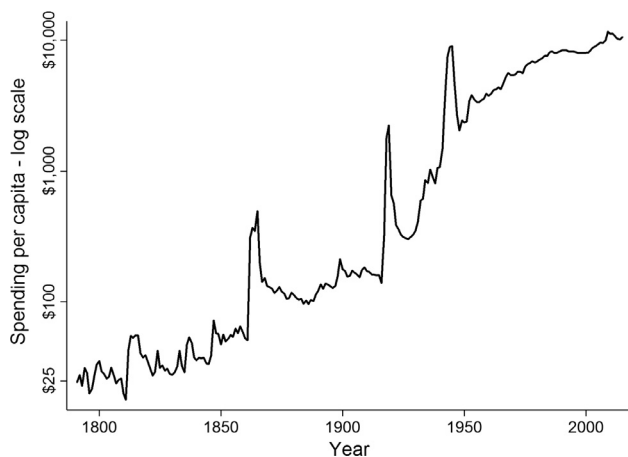

Fig. 1. US federal expenditures per capita, 1790–2015. *Data sources: Historical Statistics of the United States: Millenial Edition database,* Table Ea636–643, updated through 2015. Author's adjustments for inflation and population.

3. An empirical puzzle from US budgeting

Fig. 1 shows the size of the US federal budget from its earliest days to current times, expressed in spending per person. Of course, it is adjusted for inflation.

It is obvious that the massive wars of American history have shown their effects in the budget. (Then again, some wars—such as Vietnam, the first Gulf War, and the wars in Afghanistan and Iraq—have generated barely a blip in these long trends.) In fact, defense spending per capita rose in 1812 by 278%; in 1862 by 959%; in 1898 by 78%; in 1918 by 744%; and in 1941 by 228%. Wars certainly affect the budget, as one would expect. This would make it seem as though we need no understanding of endogenous change to understand the dynamics of a collective process like putting together the US national budget. There is no great puzzle in Fig. 1; wars can explain most of the dynamics apparent there.

Fig. 2 breaks down the budget into its domestic and defense categories, and this reveals the puzzle.

While the defense pattern seems relatively clear, the domestic spending pattern cannot be explained by the same model. Further, the defense pattern has some puzzles, such as why it sometimes declines to the pre-war level (1812, 1860, 1918) but sometimes does not (1898, 1941, 1953). Both series, when we look at their first differences, show a great number of extreme outliers. Kurtosis is the statistical measure of the degree to which a distribution has "fat tails" compared to the normal distribution. Series such as the defense series obviously have fat tails as the large blips involve dramatic changes in a single year while most years show only modest adjustments from the previous year. But the domestic series shows something similar. In fact, if we look at the kurtosis value of the change series implicit in the three series above, the values (for annual percentage change) are 69, 76, and 64 for total spending, defense, and domestic. Defense is slightly higher than domestic, but both show extremely high volatility. If wars explain the blips in the defense series, what explains the occasional extreme volatility of the domestic spending series?

One might naturally assume that there is a trade-off between spending on defense and domestic priorities. In fact, there is none. Fig. 3 shows the correlation between annual percentage change in the two series above. For each year, the Figure shows the percentage change in domestic and defense spending per capita, using the same data series as graphed above. The figure excludes 10 outlying observations, eight where defense spending spiked by over 100%, one where domestic spending did so, and one where both spiked.

There is no correlation whatsoever between change in defense and change in domestic spending. In fact, when the extreme outlier cases are included, the correlation increases substantially; this is largely due to events in 1917 and 1918 when defense spending rose by 54, then 744%, and domestic spending increased by 198 and 314%. Thus, for the most part, there is no correlation
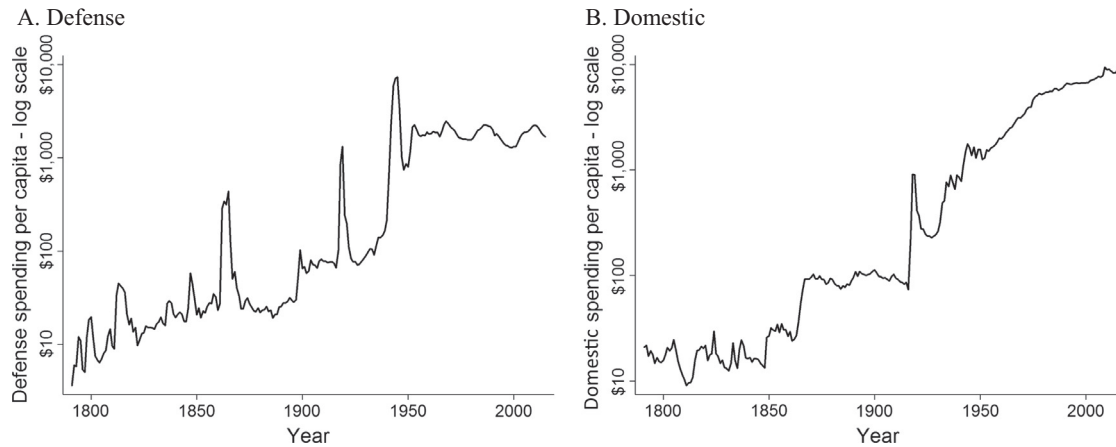
A. Defense

B. Domestic

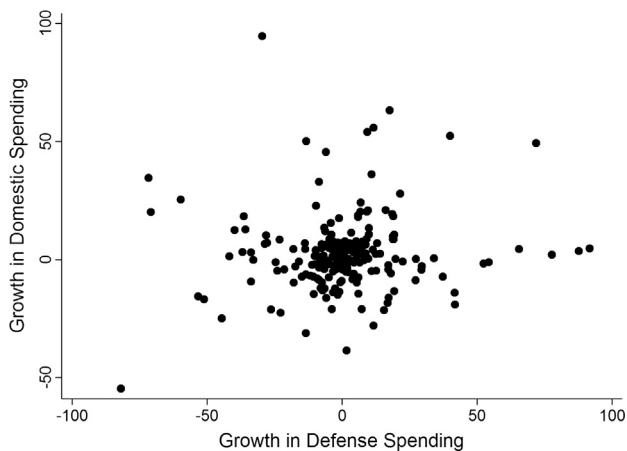Fig. 2. Defense and domestic spending, 1790–2015.

Fig. 3. Domestic and defense spending trade-offs, 1790–2015. *Note:* Data reflect annual percent change in adjusted 2015 per-capita spending. $N = 214$. Excludes ten observations where either value was greater than 100%. Pearson's $R = 0.09$. When those outliers are included, the correlation increases to 0.43.

whatsoever between spending shifts on one side of the budget and those on the other. To the extent that defense spending increases dramatically, domestic spending tends also to increase, not decrease.[1]

Why would it be that there is no trade-off between spending, or that, if there is a relationship between defense and domestic spending, it is a positive one? Are wars used as a justification for increased domestic spending? Are savings from the demobilization from war used to ramp up domestic spending? If so, we would see some kind of systematic relation in the two series shown in Fig. 3. In fact, we see no relationship whatsoever.

This is not the place for a full discussion of the dynamic drivers of US budgeting. But the articles included in this special issue, and the approach they exemplify, help us understand the puzzles implicit in the examples above. First, wars drive spending, there is no surprise there, or so it seems. But in fact each war did not induce massive spending; sometimes the spending returned to the pre-war level and sometimes not; in sum simply noting that the country was at war at a given time does not fully explain even defense spending. The recent wars in Iraq/Afghanistan, or even Vietnam are barely visible in Fig. 2; Korea, however, had a huge impact but spending never declined significantly after it. More puzzling, of course, are the next two elements: domestic spending is nearly as subject to dramatic shifts as defense spending, and (from Fig. 3), changes in spending in one category have virtually no impact at all on changes in spending on the other. If we cannot look at such exogenous factors for explanations of dramatic budget shifts, where can we find them? We need a theory of endogenous disjoint change.

4. Endogenous disjoint change

In his essay in this special issue, Epp (2017) shows a sharp contrast between decentralized market-based decision-making systems and centralized ones. No matter the inability of any single actor in a large and decentralized market fully to understand the choices they make, when averaged out across many actors, the collective decisions of these systems move slowly, smoothly, gradually. By contrast, he shows that systems characterized by centralized decision-making display disjoint change. The simplest exposition of this is in comparing currency exchange rates over time. In systems pegged to a pre-set rate, the typical change is literally zero, but as pressure builds up on rare occasions the affected state is forced, often against its will, to make a dramatic adjustment. In contrast, free-floating exchange rates, driven by markets, show smooth adjustments over time, according to Epp's analysis (2017). His analysis points to the importance of understanding how "bursty" or disjoint changes may come from a decision-making system when it is based on centralized leadership and organizational rules rather than by decentralized

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[1] Average increase for domestic spending ($N = 224$) is 5.1. In those years where defense spending increases by more than 100% ($N = 9$), domestic spending increases by 43%, on average. So there is no trade-off.

market mechanisms. Markets may generate dramatic shifts in response to exogenous shocks, but they should generate no endogenous shocks of their own. Other forms of centralized decision-making systems may produce dramatic shifts through both endogenous and exogenous processes.

Barabasi's (2005) treatment of disjoint change (or bursts) in human behavior focuses on attention. For Barabasi, the issue is a queuing process, or making decisions one-at-a-time. Most decisions can be handled quickly, but some take more time. When there are many decisions to make, some simply get put at the end of the queue, sometimes for a long period of time. Without going into detail on the Barabasi model, it explains disjoint change in the behaviors of individuals by noting how attention is allocated. Since it is not allocated efficiently, attention shifts episodically, and decisions are not made in a smooth, consistent manner. Rather, he shows, the distribution of human attention is associated with bursts. The environment may be accumulating challenges or stimuli that need to be responded to, and these may accumulate in an orderly way. But people respond to them in a disjoint manner. Therefore, to understand the output pattern of human attention, we need look not only at the stochastic distribution of inputs, but for Barabasi we must also have a better and more realistic understanding of the decision-maker themselves. Individuals (not just systems) generate bursty or disjoint patterns of outputs even when faced with a relatively well behaved (e.g., Gaussian) distribution of input stimuli.

Jones notes that "we are at a turning point in the way we approach micro-macro linkages—how much or how little of the cognitive and emotional constructions of humans we bring to our understanding of the operation of macro-level processes" (2017, 38). In particular, he notes that Simon's "canalizing" or parallel processing is fundamental to thinking of how complex organizations deal with their environments. As he writes, division of labor, the creation of specialized sub-units, and similar processes allow organizations to expand their processing capabilities, often by many orders of magnitude beyond that of individuals. But, he notes, they remain limited in some ways by the same scarcity of attention that affects human cognitive architecture. "Limited attention is a key facet of human cognitive capacity, and is reflected in organizations" (Jones, 2017, 12). Further, Jones argues that this is the fundamental assumption of behavioral organization theory, and that the cognitive link is not just a metaphor; it is a causal relationship. Because organizations are made up of humans, and because canalizing (or specializing) occasionally must involve administrative oversight and occasional involvement in the normally distributed or autonomous specialized processes, there can be powerful forces of disjoint change. That is, decentralized decision-making structures come with oversight, and oversight comes with occasional involvement of the overseeing unit. Supervisors oversee managers, and managers oversee lower managers. While the structure can be built to any scale, it can never escape the fact that each managing level is subject to its own cognitive limits, and these are always associated with human capacity.

Individual cognitive characteristics interact with institutional and social structures of collective decision-making in complex ways. Disciplinary practice has inhibited these studies, but as Jones says, we may be on the verge of a dramatic shift in our collective understandings. In fact, the essays collected here go a long way in doing exactly this.

5. Incorporating human cognition and decision making in various ways

How does the social world work if most members of the system are not paying attention to most issues most of the time? Each of the articles included in this special issue makes a different contribution to understanding more realistically how individual cognitive processes can help us understand complex organizational change. As discussed above, Epp (2017) compares market-based and centralized decision-making systems. Importantly, his analysis is not driven by a comparison of public-v. private-sector decision-making, but rather by decentralized v. centralized systems. His extended work on this topic (2018) makes clear that centralized decision-making systems in the private sector fare no better than public-sector organizations in making smooth transitions to changing environmental stimuli. The environment may be moving slowly, but the complex organization finds it impossible to respond proportionately. Rather, the same limits that apply to human cognition affect the organization, as it ignores or under-prioritizes environmental factors that deserve attention until they rise above a threshold of urgency, when the system lurches to over-respond, playing catch-up and generating in the process a signature dramatic change in outputs which has no corresponding stochastic cause. Rather the cause is endogenous, and it is the scarcity of attention. In a decentralized decision-making system, he shows, these endogenous causes can be reduced to a minimum.

Of course, they are not automatically so reduced, and in imperfect markets there can be powerful cascade effects where actors respond not to independently collected bits of new information, but rather to the observed actions of others in the market; this violation of the functioning of perfectly decentralized markets is consistent with the endogenous causes of disjoint change described here, and, where present, reflects one of the most important causes of bubbles and cascades in market systems; by definition this is an imperfection in a system that is supposed to avoid exactly this type of thing. Thomas (2017) looks into exactly this: Cue-taking and mimicking. If individuals interacting in any type of system base their actions on the behavior of those around them, the system can produce bursty results even with no exogenous shocks. Of course, cue-taking is all around us, so incorporating mimicking is a movement in the direction of a more realistic model of human behavior. Putting such assumptions into our

models of aggregated outcomes of a system can only lead to better models.

Similarly, Leech and Cronk (2017) discuss evolutionary patterns by which humans developed the capacity to form teams or groups, but also occasionally to work with members of rival groups. Their discussion of "strange bedfellow" coalitions in collective (e.g., parliamentary) decision-making suggests another way in which endogenous forces of coalition-building can help us understand occasional disjoint change. Shaffer (2017) and Hegelich (2017) provide further examples of how the intensity of attention paid to a problem, or how complex networks of communication among decision-makers can generate disjoint change.

As Jones describes, we are not ready to declare victory on the issue of how to explain endogenous disjoint change. Clearly, exogenous and easy-to-explain factors matter as well; in the example above, World War One really did have an impact on the US budget, and we need no complicated endogenous theory to understand that. However, any complete understanding of macro-level policy changes must be built on a more complete model than that. The articles brought together here take us some significant way toward building more sophisticated and realistic models of collective choice, based on more realistic models of individual cognitive processes. Based on the lack of concern with these models in the earlier literatures as discussed at the beginning of this essay, we have come a long way. We also have a long way to go in our efforts to incorporate realistic models of individual attention and cognition into models of collective action by groups. Studies of public policy and government decision making illustrate both the progress and the difficulties of this endeavor.

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