states) separated by approximately half the magnetic-field oscillation frequency, in order to accumulate as much quantum phase as possible before readout (see the figure, red curves).

This strategy is very good for estimating the value of the magnetic field when the pulse sequence began (which is then Fourier transformed as one sample of many such measurements to give a frequency estimate). Suppose we did not have to worry about the dephasing of the spin, that we had a very clean quantum system? How does this strategy fare in the estimation of the oscillation frequency itself? We see with the red curves in the figure that the dependence of the acquired phase on the frequency (steepness of the slope) is actually worse than had no control pulses been applied at (gray curves). Schmitt *et al.* realized that if the π-pulses are applied not at the nodes of the magnetic field but at the antinodes, then the slope of the phase with respect to frequency can scale as T^{-2}, giving a quantum speedup in the estimation precision (blue curves).

My own group discovered that with the right kind of quantum control, this same scaling law is possible for oscillating time-dependent Hamiltonians (*5*) and, in another instance of multiple independent discovery, recently showed with our theoretical approach to time-dependent quantum metrology that repeated π-pulses at the antinodes of the oscillating field (in this same model system) is in fact the optimal coherent control that produces the best precision that quantum mechanics allows (*6*). This improved quantum scaling (which is generally adaptive because the precise frequency is unknown) has yet to be observed experimentally but should be readily measured in experiments of this kind. The only question is which group will observe it first. ■

"...[B]oth groups could measure a 1-MHz oscillation frequency to an accuracy of less than 1 mHz..."

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ECONOMICS

How to fight corruption

Anticorruption efforts must minimize unintended effects

By **Raymond Fisman**[1] *and* **Miriam Golden**[2]

Anticorruption initiatives are often put forth as solutions to problems of waste and inefficiency in government programs. It's easy to see why. So often, somewhere along the chain that links the many participants in public service provision or other government activities, funds may get stolen or misdirected, bribes exchanged for preferential treatment, or genuine consumers of public services supplemented by "ghost" users. As a result, corruption reduces economic growth and leaves citizens disillusioned and distrustful of government (*1*). It is tempting to think that more monitoring, stricter sanctions, or positive inducements for suitable behavior will reduce corruption. But every anticorruption or antifraud program elicits a strategic response by those who orchestrated and benefited from wrongdoing in the first place. How can these unintended consequences be anticipated and avoided?

Social scientists have recently begun to measure responses aimed at evading enforcement efforts, to assess whether the solution is worse than the problem. As two recent studies show (*2*, *3*), fighting fraud, waste, and corruption is still worth the effort. Despite strategic evasion and other unintended consequences, aggregate postreform malfeasance is generally lower and—to the extent that it may be measured—social welfare higher, even in cases where strategic evasion is relatively large. But although reform tends to be beneficial overall, the more policy-makers and advisers can anticipate unintended second-order consequences, the better the initial design of policy can be. Prior analysis, pilot evaluations, and tinkering with policy design may help to head off possible strategic responses and thus dampen the negative effects of reform for social welfare.

Policy architects commonly assume that those on the receiving end will continue to behave as they did before the reform was implemented. But those affected adjust their behavior, constructing new best responses to the changed circumstances. There is an unlimited supply of anecdotes in the annals of incentive misfires. For example, a software company decided to reward programmers for fixing bugs. Not surprisingly (except apparently to the company's managers), programmers started assiduously creating new bugs that they (or their friends) could then fix. The example illustrates a general feature of these kinds of reactions: The programmers responded not only in the way that management expected (fixing bugs) but also in an unanticipated one (producing bugs).

An object lesson in unanticipated strategic responses to interdiction comes from a recent working paper, in which Meckel examines the consequences of an effort designed to reduce fraud in a large U.S. federal assistance program (*2*). The Supplemental Nutrition Program for Women, Infants, and Children (WIC) allows low-income pregnant women and mothers of young children at nutritional risk to obtain staples like milk and eggs. WIC beneficiaries are provided monthly vouchers worth specified quantities of food—for example, two gallons of milk and a dozen eggs—rather than a monetary budget.

Grocery-store responses to this quantity-based system serve as a first example of the law of unintended consequences. Enterprising small stores charged prices up to 50% higher to WIC than to cash customers, because of the former's price insensitivity (*4*). Grocers could get away with charging different prices to the two groups because the initial program design allowed sellers to record WIC purchases separately from those by cash customers, and to then mail in the WIC vouchers for reimbursement without including receipts.

To combat the resulting fraud, in 2010 the federal government mandated the adoption of an electronic system to permit direct comparison of prices paid by WIC and cash customers, using scanner data. When Meckel analyzed the scanner data from the state of Texas, she found that the technological fix worked; fraud via higher prices for WIC customers virtually disappeared. But it came with an unexpected result: Many retailers simply dropped high-nutrition, WIC-eligible products entirely. Without the fraud-induced government subsidy, it was no longer worthwhile for small grocers in high-poverty neighborhoods to carry these

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A WIC beneficiary holds her one-year-old daughter as she selects food items at the RCS Food Bank in Clearwater, Florida.

products. Among stores that continued to sell them, WIC-product prices increased markedly (by 9%), as grocers charged customers a price that was an average of the old retail price and the extortive WIC markup. As a result, residents of low-income neighborhoods, where grocery stores are few and far between, were confronted with higher prices for food staples.

These responses led to other downstream effects. When stores dropped WIC products, fewer program beneficiaries accessed their WIC products, and other low-income residents of the same area had less access to high-nutrition foods. Thus, some benefits created by features that allowed fraud in the pre-electronic WIC implementation have been shut off by the improved enforcement that accompanied fraud reduction. Nevertheless, Meckel estimates that the social welfare benefits of the electronic program are greater than the unexpected losses. She can show this because she measures both the direct and the indirect, unintended effects of the adoption of the antifraud program. But there is still a cost, and that cost is concentrated on particularly vulnerable members of society.

Unexpected effects of an otherwise effective anticorruption effort can be seen in another recent study, in which Borcan *et al.* examine the introduction of closed-circuit television (CCTV) monitoring of high school exit exams in Romania, bundled with harsher penalties for students and teachers caught cheating (*3*). Again, the program achieved its objective in reducing cheating, documented by the substantial drop in test scores that coincided with the program's introduction. But scores dropped relatively more for poor than for affluent students. One reason, the study argues, is that CCTV monitoring prevented cheating by whole classrooms of exam-takers paid for by collective bribes amassed by groups of students. With collective cheating off the table, affluent students shifted their illicit payments to individual bribes. Consistent with this interpretation, the fraction of low-income students gaining admission to high-quality universities also fell—an unintended and inequitable consequence of the new anticorruption reforms.

Unanticipated consequences do not necessarily imply that these measures were wrongheaded or that they reduced overall social welfare. Instead, the general lesson from case studies is that anticorruption reformers need to consider how those affected will respond. A tech company manager designing incentives for programmers needs to think like a programmer. In designing a WIC crackdown, you need to think like a pregnant mother, and also like a grocer. When you install CCTVs to prevent students cheating on exams, think like a desperate student who has not bothered to do his homework all year.

Prior analysis can potentially anticipate some creative responses that will emerge to undermine interdiction efforts themselves—a problem that we believe is a standard affliction of such reforms. For example, one of us (M.G.) studied the impact of nonpartisan, trained domestic election observers on election fraud carried out in polling places during the 2012 general elections in Ghana (*5*). The presence of an observer had the expected effect, reducing fraud in locations where an observer was stationed. But more fraud popped up at neighboring, unobserved polling places: presumably, when spying an observer at a polling station, those eager to commit fraud simply relocated their efforts. Strategic evasion was not unexpected, and the overall impact of election observers was a reduction in fraud, even taking successful relocation into account. But a program that built in anticipation of strategic responses might have altered the placement of observers in a way that was more effective in preventing fraud relocation.

Thus, one overall message that comes out of recent research is that anticorruption reformers need to consider second-order consequences of policy innovations. Partnering with social scientists to identify both intended and unintended consequences of reforms—and, where possible, to pilot reforms so as to identify misfires that cannot be predicted—may lead to changes in their design that result in more successful implementation. As the WIC and Romanian cheating studies illustrate, it is also especially valuable to consider whether and how policy changes affect the poorest and most vulnerable, who otherwise may be the unintended victims of anticorruption reforms. ■

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