The comment is offered, "Venture capital is not a source of financing for the kind of early-stage research needed by public agencies and that the [Small Business Innovation Research] program funds"**—the response to which is,** "While...the number of 'micro-financings' (those of under $1 million) have decreased in recent years, venture investments in early-stage companies have increased...[and] venture investors are increasingly willing to invest in technologies that they have traditionally shunned." **And the potential for carbon sequestration in soil with the use of nitrogen fertilizers is examined through analysis of the carbon costs involved.**

Surveying the SBIR Program

In his Policy Forum "The problematic venture capitalist" (*Science*'s Compass, 11 Feb., p. 977), Josh Lerner raises several issues to challenge the supporters of the Small Business Innovation Research (SBIR) program and to ensure that those managing and funding the program remain focused on the program's true public objectives. A reader could, however, draw some erroneous inferences that I would like to address.

First, the SBIR program is not a venture capital program. Its primary objective is to fund research that enhances public programs sponsored by, for example, the National Institutes of Health and the National Aeronautics and Space Administration. When the SBIR program was created in 1982, Congress wanted to ensure that tax-supported research and development was enriched by the innovations and creativity that are found in the small-business, high-technology sector of the economy, thus maximizing the purchasing power of tax-financed research and development. And the program's research decisions were to be subject to the same rigid peer review process that exists in evaluations of university research.

Second, Lerner's effort to characterize the program as a venture capital program and to question the appropriateness of public involvement in matters the private sector could finance is unsupported by any evidence of the market's interest in funding research that focuses on governmental needs. The data on venture capital disbursements reveal a clear trend away from the smaller deals (those under $1 million), which are the ones most relevant to the participants in the SBIR program. There has been a dramatic expansion in venture capital, as Lerner notes, but that expansion has excluded the smaller-scale ventures needed by the type of small, innovative technology firms the SBIR program supports. In the most recent year of data, only 3% of venture capital deals were under $1 million. Data also show that the average venture capital deal size was $13 million in 1999 (*1*).

In addition to moving away from smaller-sized ventures, venture capital funds tend to require a shorter time to exit from the venture than is appropriate for most SBIR firms, and they tend to be concentrated in a few "fad" industries at a time. Witness the NASDAQ escalation in technology investment. Research supported by SBIR firms, in contrast, covers a broad spectrum of technology identified with public rather than private priorities.

Finally, while I agree with Lerner that the performance of publicly funded programs should be researched to measure their impact, it is important to keep in mind the objectives of these programs—in this instance, enhancement of public missions and national priorities. Any research must be objective and not depend on subjective responses to survey questions, as evaluations by some awarding agencies and the U.S. General Accounting Office have done, which Lerner mentions. Lerner's 1996 research (*2*)—probably the most objective thus far—revealed that researchers initially funded by the SBIR program ultimately attracted venture capital, and their innovative firms grew faster than their matched, nonfunded counterparts. Venture capital is not a source of financing for the kind of early-stage research needed by public agencies and that the SBIR program funds.

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2. J. Lerner, *Natl. Bur. Econ. Res. Work. Pap. 5753*, 1996.

Several comments by Lerner concerning the SBIR program are at odds with the point of view from the small business and entrepreneurial community. Comparatively, this program has enjoyed enormous successes to date. Dollar for dollar, SBIR successes are far greater than those produced over the same time period either by the not-for-profit research institutions, where there is no economic incentive to commercialize, or at the large aerospace firms, where it is difficult to nurture innovation.

Regarding the "political distortions" Lerner mentions, it seems unlikely that the SBIR awards are as subject to political pressures as his Policy Forum would imply. In the selection of SBIR awardees, proposals are generally evaluated by "peer" groups gleaned from industry and academia, not just from the government. Even when internal government reviewers are used, they are usually from diverse organizations. These features make it unlikely that all the review committees could be subject to political pressure. In addition, neither of the effects discussed by Lerner need be characterized as a "political" distortion; rather, the first—more awards in some regions—is a geographic one (high-technology folks do tend to flock together; thus, more applications come from these regions). The second—single-award winners commercialize better than multiple-award winners—is simply a practical one in that those who remain focused on the goal tend to do better in the commercial marketplace.

With respect to commercialization rates, studies that include firms awarded SBIR funding before 1992 are problematic in that they do not fairly represent the current situation and class of SBIR firms. The funding agencies have recognized the "SBIR mill" issue that Lerner refers to (companies that capture a disproportionate number of awards) and are moving to correct it. Evaluators now obtain and "score" the commercialization track records of applicants such that poor records are penalized in the proposal evaluations.

In addition, Lerner's commercialization numbers referred to in the article could be considered skewed because SBIR mill companies do not commercialize well. A rule has been instituted to address part of the problem: The principal investigator for a proposal must be primarily employed by the bidding firm, so that those preparing the proposal have a vested interest in its success. The new rule is making a difference, which is only now beginning to show up in the commercialization results. The U.S. Small Business Administration estimates that 40% of companies now receiving phase II SBIR funds are going on to successful commercialization. The SBIR and STTR (Small Business Technology Transfer) (*1*) programs are rapidly changing to such an extent that there really is no

long-term history that can be fairly evaluated yet.

Even if his data are negatively skewed, the numbers Lerner presents are still impressive in favor of the SBIR program. And as Lerner notes, many past SBIR winners still believe in the program—to such an extent that they continue to support it for the rest of us long after they are no longer eligible to bid (too large and successful) themselves.

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References

1. STTR is the same as SBIR, except that companies are teamed with a not-for-profit research and development institution.

Response

A few issues presented by Glover and Davis in their letters deserve further discussion. In particular, it is important to reiterate three points.

First, commercialization is a major—and increasingly important—objective of the SBIR program. A reader of Glover's letter might conclude that the program was solely designed to use small businesses to meet federal research needs. Encouraging commercialization, however, has been a crucial goal since the program's inception. This was made particularly explicit in the 1992 act, which stated that projects should be selected on the basis of "scientific and technical merit and [the] feasibility of ideas that appear to have commercial potential." The legislation also instructed agencies to assess as a part of the award process such indicators as the small business's previous track record in commercialization and the existence of funding commitments from private financiers. Given the importance of commercial outcomes to Congress at the time of the program's enactment and reauthorization, it seems reasonable to empirically explore the commercial success of SBIR awardees.

Second, the financing environment is changing for young firms. The amount invested by venture capital organizations has increased dramatically in recent years. While, as Glover points out, the number of "micro-financings" (those of under $1 million) have decreased in recent years, venture investments in early-stage companies have increased: from $840 million in 1991 to nearly $11 billion in 1999. Rather than turning their backs on young firms, venture capitalists are funding them to a greater extent than ever; venture capitalists are now willing to provide these firms with significantly more resources. Moreover, venture investors are increasingly willing to invest in technologies that they have traditionally shunned, such as energy. Thus, the suggestion that venture capital is not an option for the "early-stage research needed by public agencies" is problematic.

Third, much remains to be learned about the SBIR program. Davis says that "SBIR successes are far greater than those produced by...not-for-profit research institutions... [or] the large aerospace firms." This issue—although clearly important—has not yet been the subject of systematic economic scrutiny. Similarly, for reasons discussed in my Policy Forum, the long-run effect of recent efforts to reform the SBIR program (that is, to increase the emphasis on commercialization) will only be known in the future.

And lastly, to clarify two items, my research has been based on externally verified performance measures and not on surveys, as Glover warns against. (Survey responses, as discussed in my Policy Forum, may be subject to numerous biases, particularly in evaluations of highly politicized initiatives such as the SBIR program and

the Advanced Technology Program.) Second, the regional disparity highlighted in my Policy Forum did not relate to the concentration of awardees. Rather, I emphasized the very poor performance of awardees in regions without a vibrant high-technology community already.

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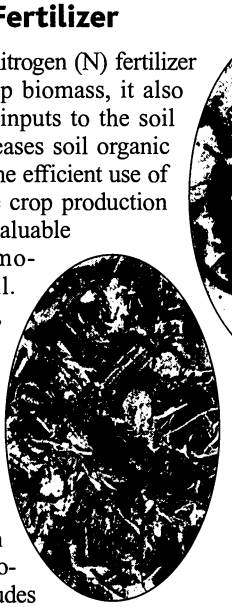
Carbon Cost of Applying Nitrogen Fertilizer

When the addition of nitrogen (N) fertilizer leads to increased crop biomass, it also augments carbon (C) inputs to the soil and, hence, often increases soil organic matter. Consequently, the efficient use of fertilizer N to increase crop production has also been found valuable for sequestering atmospheric carbon in soil. William H. Schlesinger, however, in his Policy Forum "Carbon sequestration in soils" (*Science*'s Compass, 25 June 1999, p. 2095) analyzes results from a 20-year experiment in Kentucky on conventional-till and no-till corn (*1*) and concludes that "the full carbon cost of N fertilizer...would effectively negate any net carbon sink as a result of the application of the fertilizer." These costs include the CO_2-C emitted during fertilizer manufacture, storage, transport, and application. The three carbon cost factors (moles of CO_2-C emitted per mole of N applied) documented by Schlesinger are 0.375 (stoichiometry of Haber-Bosch reaction), 0.58 (carbon cost of fertilizer manufacture) (*2*), and 1.436 (carbon cost of fertilizer manufacture, storage, transport, and application) (*3, 4*).



Young organic matter extracted after 13 years from soil receiving no N (above) compared with soil receiving N at 50 kg ha^{-1} year^{-1} (right). Black material is charcoal.

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We analyzed the same data and found that they do not support the conclusion that the carbon costs of N fertilizer negate the associated carbon sequestered in soil. Using the cost factor of 0.58 leads to ranges of CO_2-C released from fertilizer (as a proportion of sequestration) of 11 to 27% under conventional-till practices and 9 to 19% under no-till practices. The highest factor (1.436) and the fertilizer rate with the highest carbon cost would make the proportional costs increase by a factor of 2.48 to 66% under conventional tillage and 48% under no tillage—not the 100% required to negate any net carbon sequestration. Schlesinger bases his conclusion on the use of an unrealistically high N application rate of 336 kilograms per hectare per year (kg ha^{-1} year^{-1}). Thus, even with the most comprehensive (conservative) cost factor and highest N rate, the carbon cost of fertilizer N to increase crop production is less than the carbon sequestered in soil at the Kentucky site.

Farmers, however, add nutrients to soils to replenish those exported with harvested products in a way that makes economic sense. For example, nonfertilized corn in the Kentucky experiment removed on average 65 kg N ha^{-1} year^{-1}, whereas corn fertilized with 84 kg N ha^{-1} year^{-1} removed 97 kg N ha^{-1} year^{-1}. How much more nitrogen will farmers add? The answer depends on crop response to fertilizer, fertilizer price, and grain price. Using data from the Kentucky experiment and setting marginal cost equal to marginal return, with corn prices at $78 per megagram and fertilizer at $0.50 per kilogram, we calculate that the optimum rate of N application would be 133 kg N ha^{-1} year^{-1}, regardless of tillage method (*5*). Proper fertilization, in combination with reduced tillage, can produce net carbon sequestration in soil and sustain productivity.

We conclude that N fertilizers, when used to increase crop biomass under the conditions of the Kentucky data, result in positive net carbon sequestration. Carbon sequestration in soils has limits, and it is sensitive to management, soil conditions, and climate. However, the practice offers one way for society to reduce the potential for undesirable climatic change. Failure to recognize its value may lead not only to loss of future opportunities for soil carbon sequestration, but also to policies that inadvertently eliminate carbon sequestration that accrues from progressive agricultural practices.

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