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A reply to 'Multiyear versus single-year drought: a comment on Peck and Adams'

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We appreciate Tihomir Ancev's interest in our research on the economic consequences of multiyear droughts (Peck and Adams 2010). Ancev raises two concerns about our paper in their comment. First, he is concerned that our main conclusion (i.e. drought in one year can influence the effects of drought in subsequent years) may be an artefact of our representation of crop interdependencies as 'agronomic rules.' He asks, specifically, whether our conclusion would change if we allowed the model to make trade-offs between drought management and pest and disease management. Ancev's second concern is that our conclusion does not hold for all drought scenarios we analysed. Because our conclusion does not hold universally (across all states of nature in the analysis), Ancev questions its validity. He closes by recommending an alternative approach that would compare the effects of single versus multiyear drought events.

Ancev is correct that agricultural producers facing drought are not rigidly bound by agronomic rules, but instead face trade-offs between crops that help manage scarce water resources and those that help manage pests and diseases. Producers may violate agronomic rules if they are more concerned about mitigating the financial impact of drought in the current year than the financial impact of increased pests and diseases in future years. Continuous production functions would capture the yield effects of alternative crop sequences more precisely and allow marginal trade-offs between drought and pest/disease management. Unfortunately, we found no such production functions in the literature for our study area's major crops (wheat, corn, sugar beets and onions). El-Nazer and McCarl (1986) estimated production functions for wheat and corn in the Pacific Northwest, but their study did not include beets or onions, so their production functions do not capture the yield effects of sugar beets or onions on wheat and corn, or *vice versa*. Nor were adequate production data available from the study area to estimate functions that capture crop interdependencies.

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Our use of agronomic rules is based on interviews with producers in the region. These producers indicated that agronomic rules about crop rotations are an important means for managing diseases and pests, maintaining soil quality, and minimising input costs. Producers also expressed a general belief that the costs of deviating from agronomic rules generally outweigh the benefits; that is, local agronomic rules already reflect economically optimal crop rotation practices under most growing conditions. No producers indicated that they deviate from agronomic rules as a drought management strategy.

We believe the crop rotation rules used in our study accurately reflect farmer behaviour (in this region at least) and are preferable to more restrictive approaches, such as pre-determined crop rotations. However, the more important issue from the standpoint of Ancev's comment is whether use of these agronomic rules restricts model solutions in ways that invalidate our core finding. Agronomic rules clearly provide less flexibility in the model's crop choice than would continuous production functions. Consequently, net revenue arising from our model should be less (or no greater) than net revenue if we used continuous functions instead. It is evident, however, that agronomic rules capture the fundamental dilemma producers face given uncertain water supplies and interyear crop dynamics; decisions they make in response to drought in the current year have implications for future cropping opportunities and hence their vulnerability to future years of drought. As long as our model captures the farm system's interyear crop dynamics (using either agronomic rules or continuous production functions), the result that drought can generate impacts beyond the years in which it occurs will hold.

A simple example illustrates that our conclusion is not an artefact of agronomic rules and that it would also hold if continuous production functions were used. Suppose a producer violates one of the agronomic rules by planting wheat in the same field in two consecutive years. They might do so because they believe having a larger portion of their total crop acreage in a drought-tolerant crop such as wheat reduces the expected cost of drought. The benefit of this decision is the ability to manage scarce water resources more effectively. However, the decision's cost is that consecutive wheat crops increase cereal cyst nematode populations to densities capable of reducing yield (Smiley and Yan 2010). Assume the producer decides, in the third year, to address the nematode problem by planting an alternative crop in the infested field. The chosen crop is presumably less drought-tolerant than wheat; otherwise, the producer would have planted it in the second year instead of wheat. If drought occurs in the third year, the producer experiences greater economic losses than if they had planted wheat, because the alternative crop requires more water and is more sensitive to deficit irrigation. Even if the producer's gains in the second year outweigh their additional costs in the third year, the conclusion is the same: decisions made in preparation for, or in response to drought in the second year influenced the effects of drought in the third year.

To complete this multiyear example, suppose the producer decides in the third year to instead plant wheat in the same field (for a third consecutive year). When drought occurs in the third year, wheat will be especially vulnerable to the burgeoning nematode population (Smiley and Yan 2010), and yield losses will be larger than if nematodes were not so abundant (i.e. than if the producer had not planted wheat in the second year). Regardless of which crop is planted in the third year, the producer's decision to plant wheat in the second year (to reduce the expected cost of drought, at the expense of future pest management) influences the cost of drought in the third year. Replacing agronomic rules with continuous production functions would not change the main conclusion that drought preparedness and response activities (and the resulting financial impacts of drought) in one year can influence the effects of drought in subsequent years. This discussion highlights a need, nonetheless, for continuous production functions that describe interdependencies between a wider range of crops, and a more complete understanding of the short and long-term benefits and costs of deviating from typical crop rotations.

Ancev's second concern is that our conclusion does not hold for all drought scenarios analysed within our model. Table F1 in the supplementary appendix to Peck and Adams (2010) does reveal that drought in one year does not always influence the effects of drought in subsequent years. Specifically, in five of 64 water supply scenarios, drought in previous years does not influence the effects of drought in subsequent years. In these five scenarios, drought preparedness and response activities are sufficiently moderate that they do not impose binding constraints for cropping activities in subsequent years. If the initial crop plan has sufficiently low water requirements, only subtle adjustments (e.g. deficit irrigation) are necessary to mitigate water shortages. Deficit irrigation imposes no constraints on cropping activities in subsequent years and therefore would not alter the effects of a subsequent year of drought.

In two of 64 scenarios, drought in one year actually reduces the effects of drought in a subsequent year. Again, characteristics of the crop plans in place when drought occurs dictate the extent of mitigation necessary to address a water shortage, and hence the extent to which current and future crop plans might have to be altered. If the initial crop plan's water requirements are sufficiently high, dramatic mitigation measures may be necessary. Some mitigation measures actually improve a producer's ability to mitigate drought in subsequent years. Suppose, for example, a producer fallows/abandons a wheat field in response to drought. This creates the option to re-plant the field to wheat the following year (without violation of agronomic rules), which would improve the producer's future drought management capabilities.

The conclusion that a multiyear drought can be more than the sum of its parts holds for 57 of 64 water supply scenarios and is therefore in our opinion quite robust. This finding provides evidence that the effects of an individual year of drought *can* depend on the occurrence of drought in previous years, although such interdependence is not *guaranteed*. We would have liked to have presented and discussed the few exceptions to our conclusion in our original paper, but lacked sufficient space to do so.

Ancev concludes the comment by recommending an alternative approach for comparing the effects of single versus multiyear drought events. In response, we would like to clarify that our paper's purpose is *not* to compare the effects of single versus multiyear drought events. It was not our intent to determine, for example, whether a 3-year drought generates larger impacts than a 2-year drought, or a 2-year drought generates larger impacts than a 1-year drought, although Table F1 can be used to answer such questions. Our purpose is instead to determine whether the effects of individual years of a multiyear drought event are independent of one another, i.e. whether the effects of a multiyear drought can be decomposed into independent annual components. The simulation procedure Ancev recommends in his final paragraph would not address this question. However, it would contribute other interesting insights about multiyear drought.

References

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