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Climate Change, Heat Stress, and U.S. Dairy Production

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What Is the Issue?

In many parts of the United States, climate change is likely to result in higher average temperatures, hotter daily maximums, and more frequent heat waves, which could increase heat stress for livestock. Heat stress is characterized by changes in respiration, heart rate, sweating, blood chemistry, and hormones. It can also alter the metabolism of minerals and water and the digestion of nutrients. Animals generally increase their water intake and reduce their feed intake. Depending on the species, heat stress can reduce meat and milk production and lower animal reproduction rates. Livestock producers can mitigate heat stress with shade structures, cooling systems, or altered feed, but these methods increase production and capital costs. Dairy cows are particularly sensitive to heat stress; higher temperatures lower milk output as well as its fat, solids, lactose, and protein content.

The U.S. Global Change Research Program (USGCRP) recognizes that increased heat stress will increase livestock production costs, lower feed efficiency, and compromise livestock health. While the physiological and production responses to heat stress have been widely studied, there have been no attempts to quantify the costs to the U.S. dairy industry of climate change-induced heat stress. In this report, we use operation-level economic data coupled with finely scaled climate data to estimate how the local thermal environment affects U.S. dairies' effectiveness at producing outputs with a given level of inputs. We use this information to estimate the potential decline in milk production in 2030 resulting from climate change-induced heat stress.

What Did the Study Find?

The report found evidence of a significant negative relationship between heat stress and the productivity of U.S. dairies. In 2010, heat stress lowered the value of annual milk production for the average dairy by about \$39,000, which equates to \$1.2 billion in lost production for the entire dairy sector.

Climate model predictions indicate that, on average, U.S. dairies will experience an annual temperature increase between 1.45 and 2.37 degrees Fahrenheit by 2030. Assuming no adjustments in milk prices, we estimate that the additional heat stress from climate change will in 2030:

- Lower milk production for the average dairy by 0.60 to 1.35 percent, depending on the climate model used;

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- Cause some production loss to almost all dairies, with 4 to 18 percent of dairies experiencing a loss greater than 2 percent;
- Lower total annual production at the State level between 0.05 percent and 4.4 percent, with the greatest losses occurring in Southern States; and
- Lower receipts from total annual milk production at the national level by \$79-\$199 million, at 2010 prices.

Allowing for higher market prices resulting from the contraction in milk production, we estimate that additional climate change-induced heat stress will in 2030:

- Lower consumer welfare by \$64-\$162 million because of higher milk prices, and
- Lower producer welfare by \$42-\$108 million because of higher production costs.

Allowing for a continuation of past trends in dairy location and scale of production does not substantially alter the magnitude of the estimated effects of climate-induced heat stress on dairy production. Production effects in the study were mitigated only slightly if dairies moved out of regions forecast to undergo the greatest increases in heat stress, because dairies in these regions contribute relatively little to national output.

While the estimated reductions in output are modest over the next 20 years, losses from heat stress could increase substantially in later decades, depending on the extent of future climate changes. However, there is potential scope for adaptation to future climate change. Because the effects of climate change-induced heat stress will likely increase gradually over time, costs can be mitigated by research and development into heat mitigation technologies and practices. Possible innovations include energy-efficient cooling for animal housing, the adoption of heat-tolerant breeds, and improvements in scientific knowledge about the interactions among feed, nutrition, and heat stress.

How Was the Study Conducted?

This report uses operation-level economic data and finely scaled climate data to estimate how the local thermal environment affects the technical efficiency of U.S. dairies. We first estimate the average annual heat load for livestock—the amount of humidity-adjusted heat that animals are exposed to—in different regions using 16 years (1990-2005) of daily weather data. We match this climate information with farm production data drawn from the Agricultural Resource Management Surveys of U.S. dairies conducted jointly by USDA's Economic Research Service and National Agricultural Statistics Service in 2005 and 2010. We then estimate the relationship between the average annual heat load and dairy productivity using an econometric production model. Results from this model provide information about how much milk output would decline if there were an increase in the heat load.

Next, we use forecasts from four global climate models to provide a range of predicted heat loads in different regions in 2030. Using these climate forecasts and estimates from the econometric production model, we forecast the potential milk production losses associated with climate change. We explore how the magnitude of the production effects varies across States. We also explore how these effects would differ if geographical growth patterns in milk output were to follow historical trends, or if production were to shift from States experiencing relatively large increases in temperature to States experiencing smaller increases.