Nicholas Institute for Environmental Policy Solutions
Duke University

Implications of Alternative Crop Yield Assumptions on Land Management, Commodity Markets, and GHG Emissions Projections

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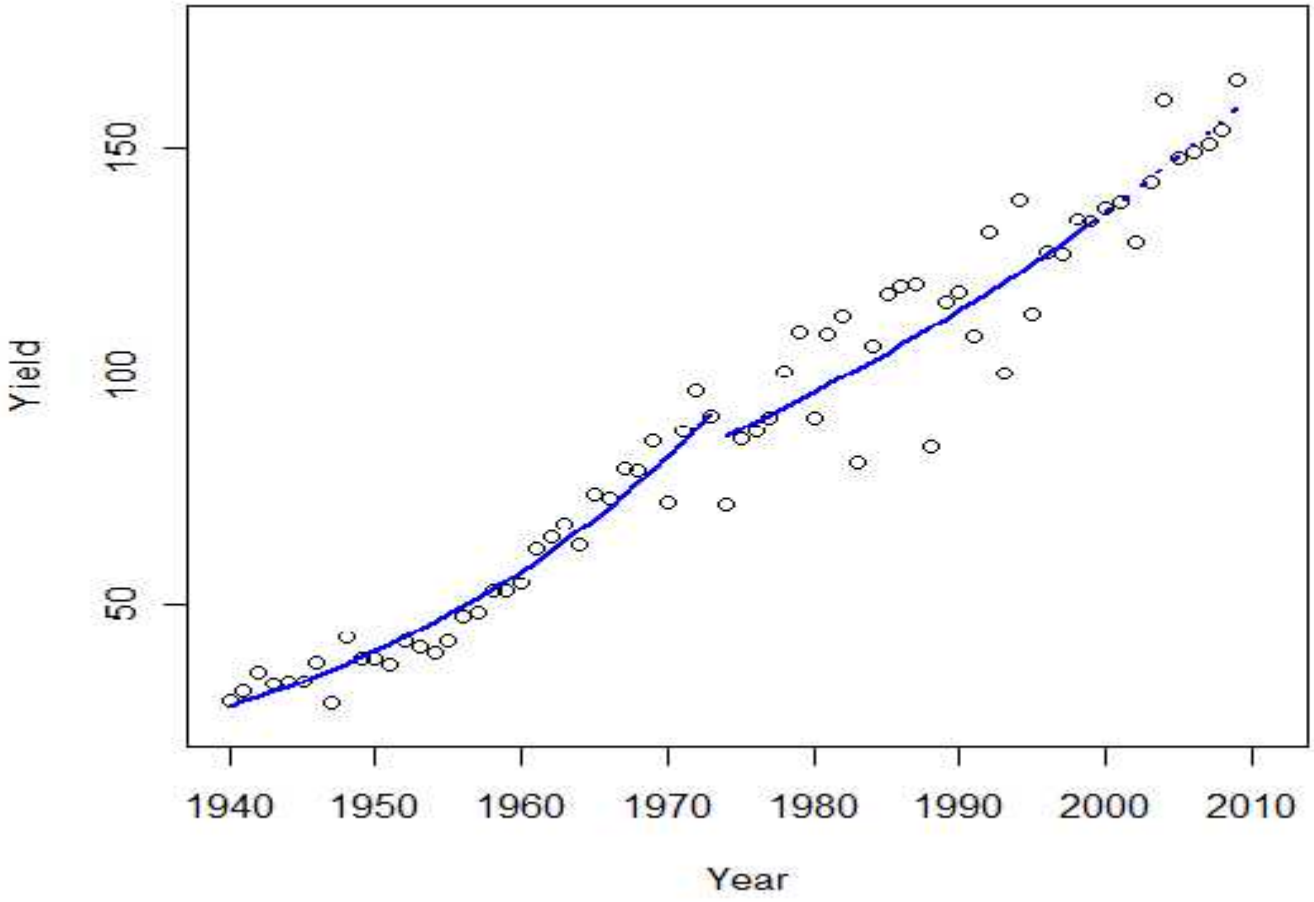
Presentation Outline

1. Modeling the relationship between agricultural productivity, emissions and mitigation
   - Potentially ambiguous relationship

2. Simulation analysis
   - Land management responses to alternative productivity growth futures
     - Application of FASOMGHG

Is Agricultural Productivity Growth Slowing Down?

- **Corn** yields over time–
  - Evidence that the rate of technological progress has declined



Consequences of GHG Mitigation in Agriculture

- A successful GHG offset program likely incentivizes trade-offs between carbon and production
  - Especially true in the U.S.
  - Raises commodity prices (Baker et al., 2010; Jackson and Baker, 2010)
  - Food vs. Carbon?

- Agricultural intensification and productivity improvement can be a source of abatement
  - Recent literature supports this (Burney et al., 2011; Choi et al., 2011)
    - Reduces deforestation rates and emissions
    - This effect likely varies region to region, system to system

Can ***Exogenous*** Productivity Gains Reduce Emissions and/or Improve Mitigation Potential?

- Depends…
  - More production on less land
    - Could free up land for mitigation purposes
  - Greater productivity raises agricultural land rents
    - Could induce additional land use change, production intensity, and hence emissions

- It is important to understand how ***exogenous*** productivity improvements might impact ***endogenous*** management choices
  - Extensive and intensive margin shifts are possible
  - Partial equilibrium modeling can help address this question

Modeling Emissions/Mitigation across Productivity Pathways

- US Forest and Agricultural Sector Model with Greenhouse Gases (FASOMGHG) applied
- Multiple productivity growth scenarios are extrapolated using parameters estimated from USDA-NASS yield data from 1960-2009
  - Procedure applied to all major row crops and livestock commodities, testing multiple functional forms and for structural break points in time
    - ***High*** "best fit" scenario
    - ***Medium***: Growth parameters restricted to be linear
    - ***Low:*** Growth parameters restricted to the lower bound of a 90% confidence interval, using linear coefficients from above
- Simulations performed under baseline conditions, and with multiple mitigation price incentives
  - \$15, \$30, \$50 and \$100/tCO_2e

Key Productivity Improvement Parameters

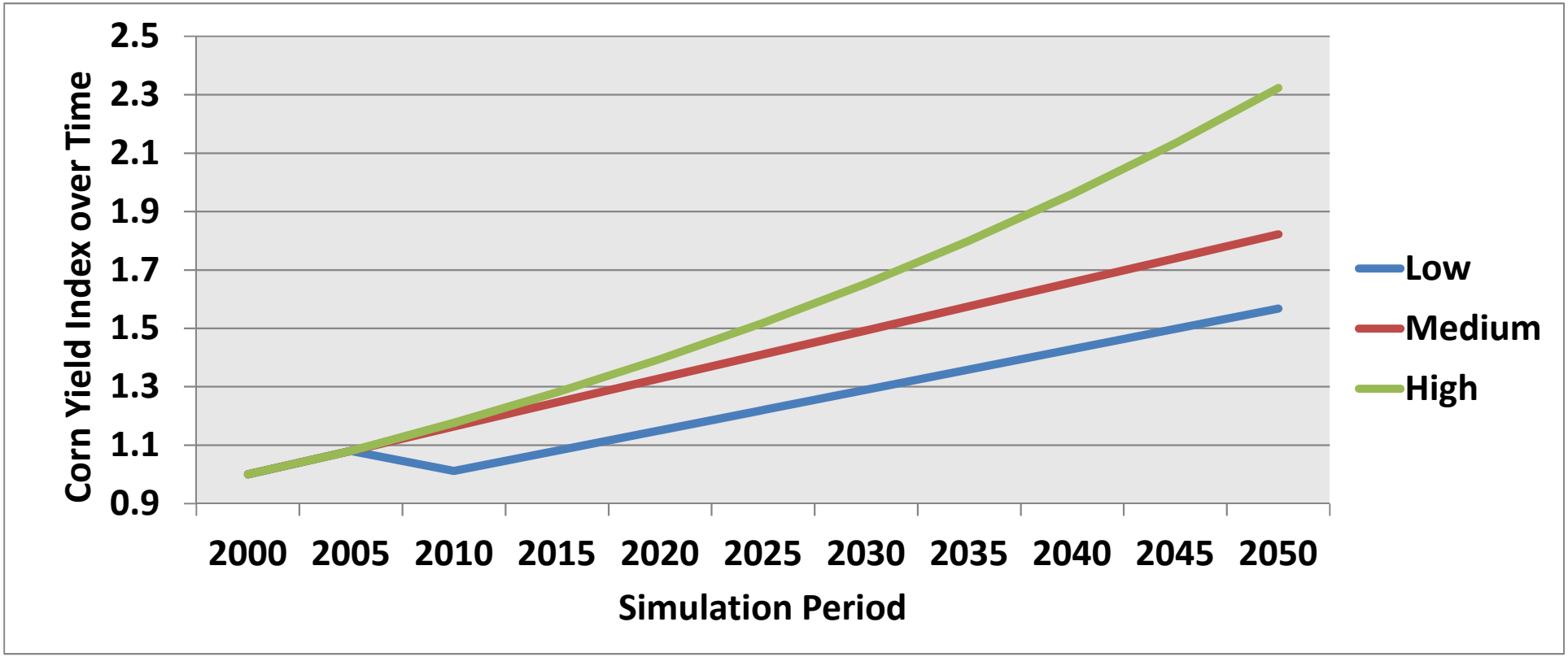
1. ***Exogenous* productivity improvement**
   - Estimated statistically, extrapolated over time
     - high, medium, and low scenarios as described above

2. ***Exogenous* intensification parameters**
   - Input use elasticities requiring additional input use for percentage yield change

3. ***Endogenous* intensification options**
   - Multiple N application rate options (70%, 85%, 100% and **115%**)
   - Irrigated or dryland
   - Nitrification inhibitor option

4. ***Endogenous* productivity improvements**
   - Through land allocation and crop mix decisions

Example- Corn Productivity by Simulation Scenarios



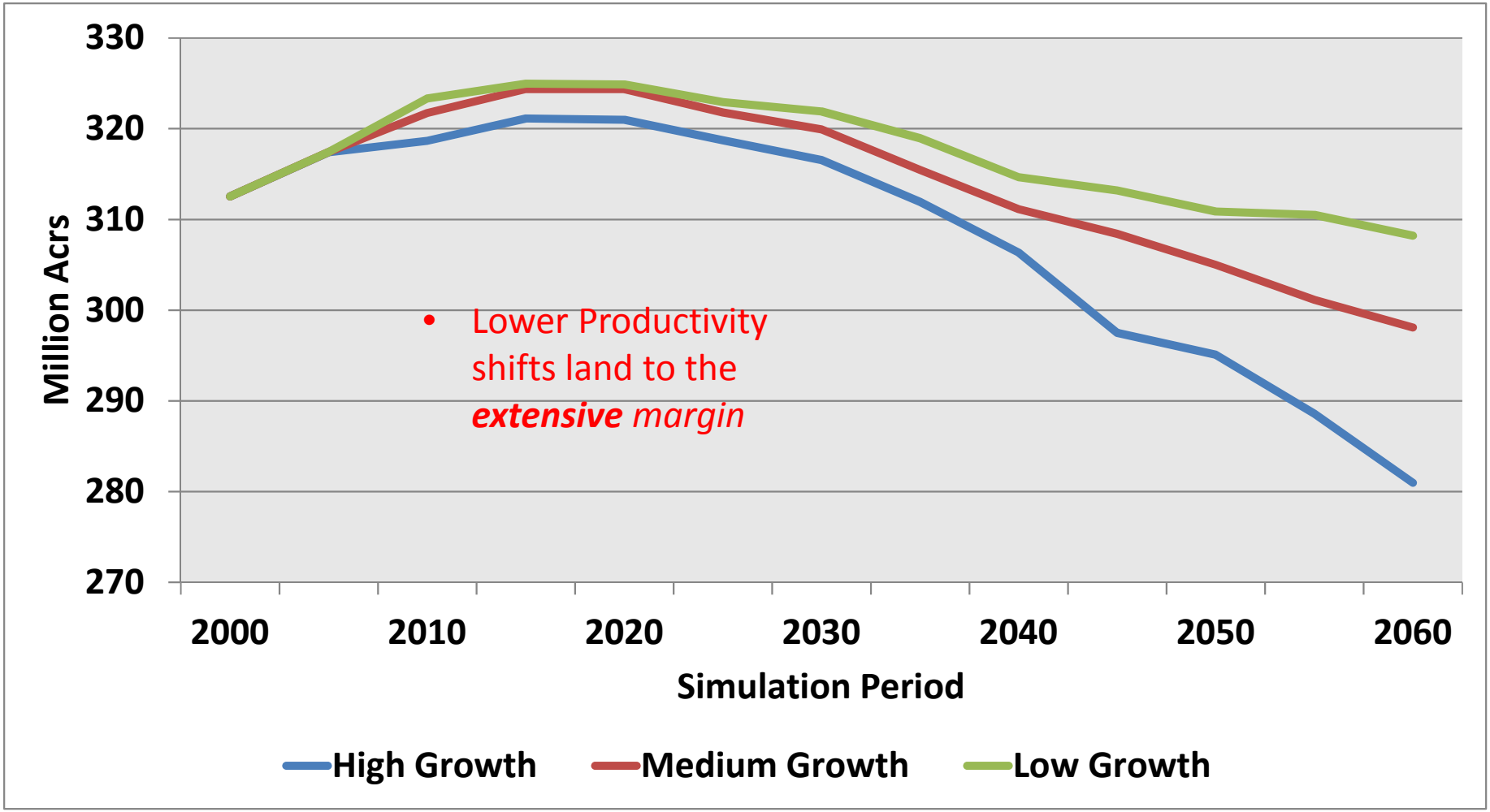
- Note- The only major difference between the *"high"* and *"medium"* growth scenarios is the corn yield projection

Preliminary. Do not cite.

Results

- Baseline
  - Vary baseline productivity
    - Evaluate implications for land use, management, markets, and emissions
- GHG Mitigation scenarios
  - Examine mitigation potential by CO_2 price and productivity scenario

Cropland across Productivity Scenarios



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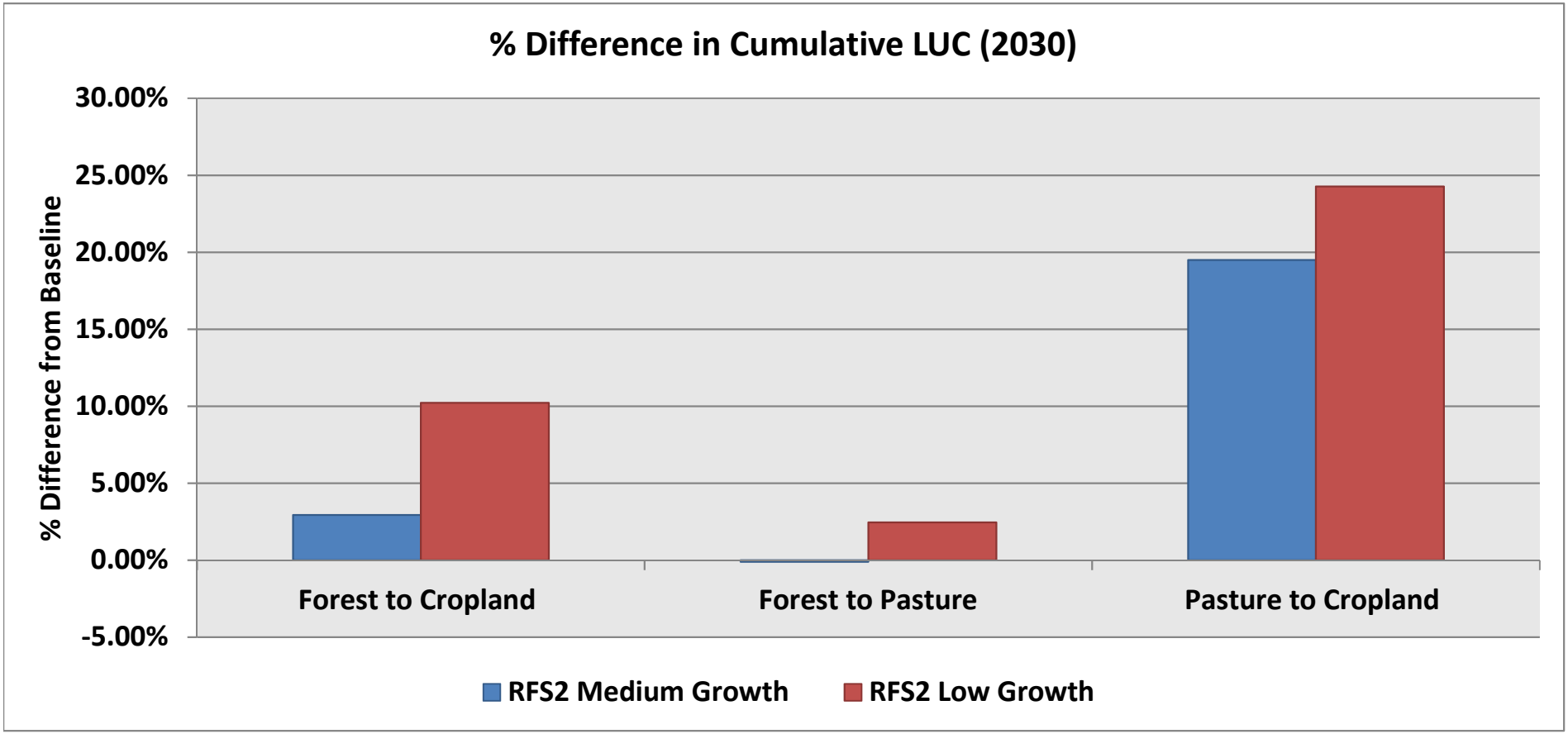
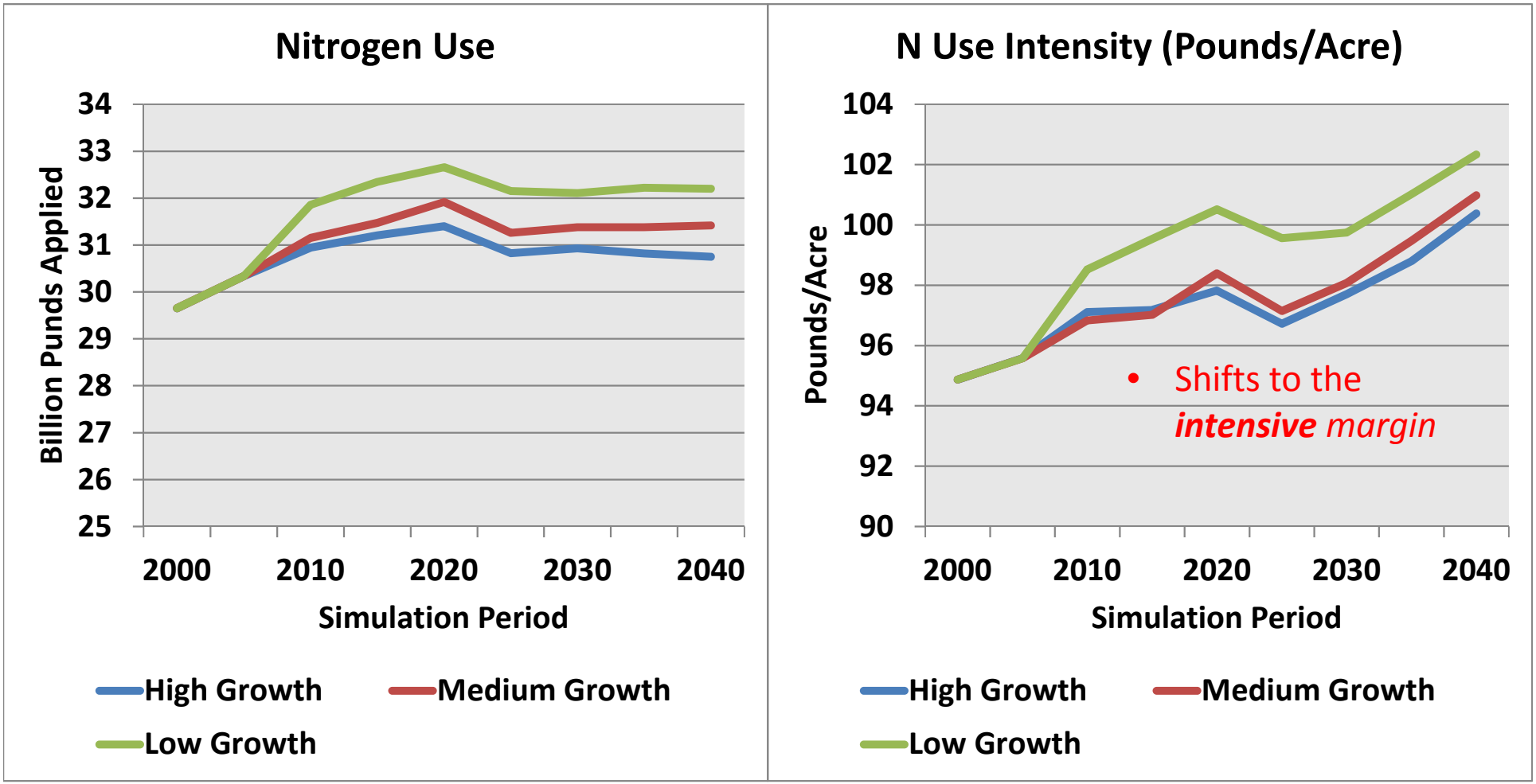
Effect of Productivity Growth on Land Expansion into Agriculture



Nitrogen (N) Use across Productivity Scenarios



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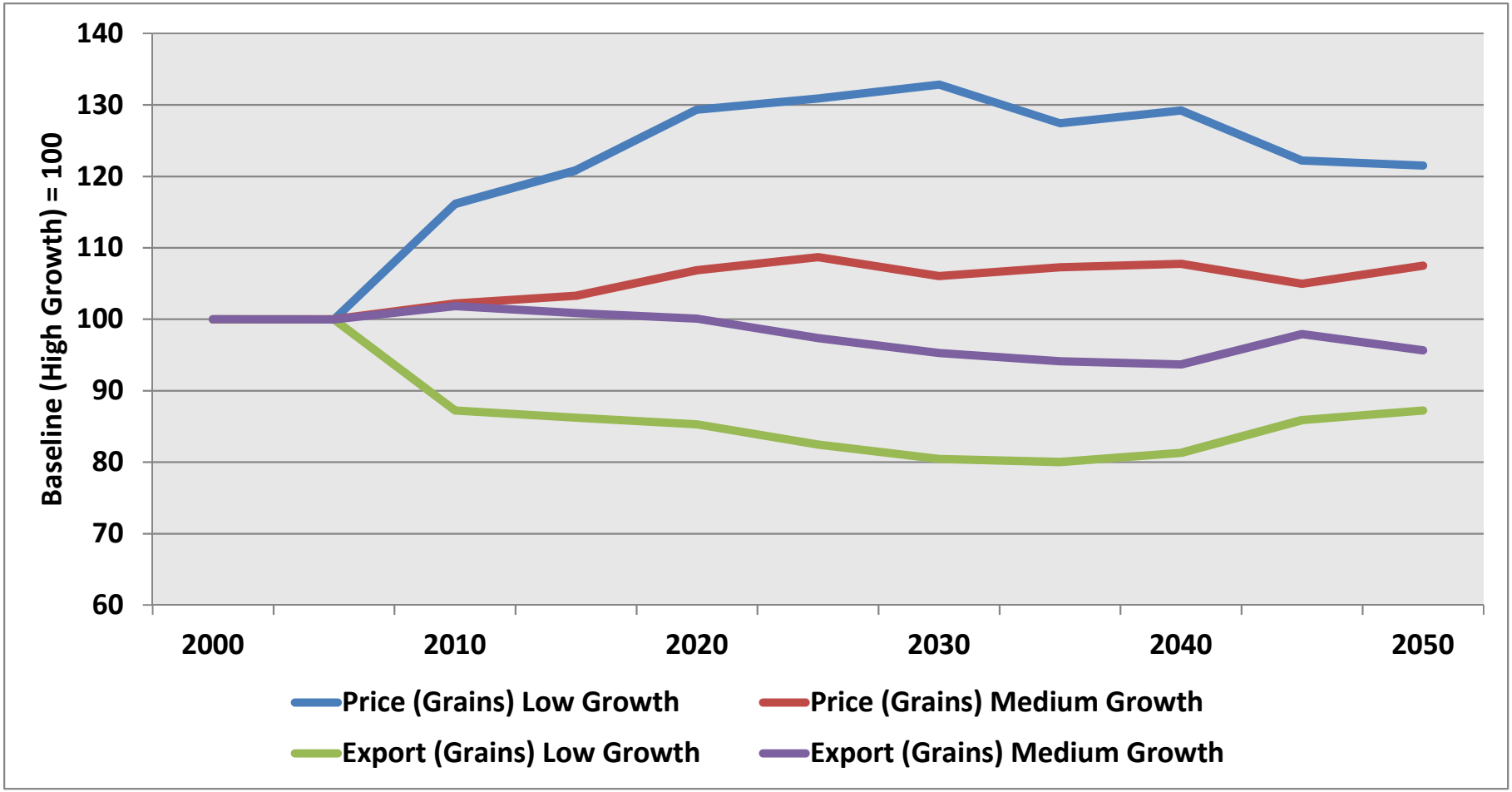
Baseline Commodity Prices/Exports



- Higher prices, lower total production, even with extensive and intensive margin shifts

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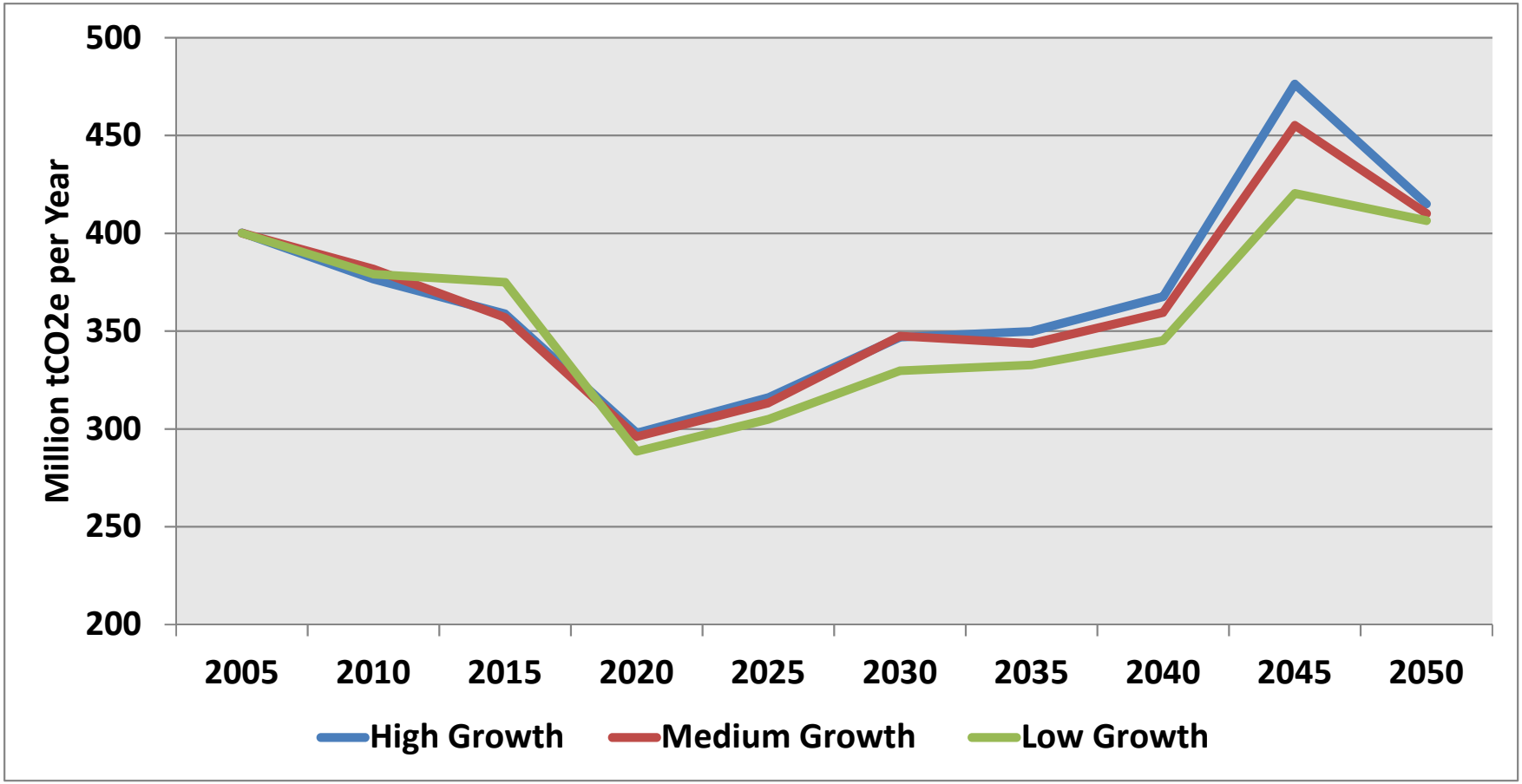
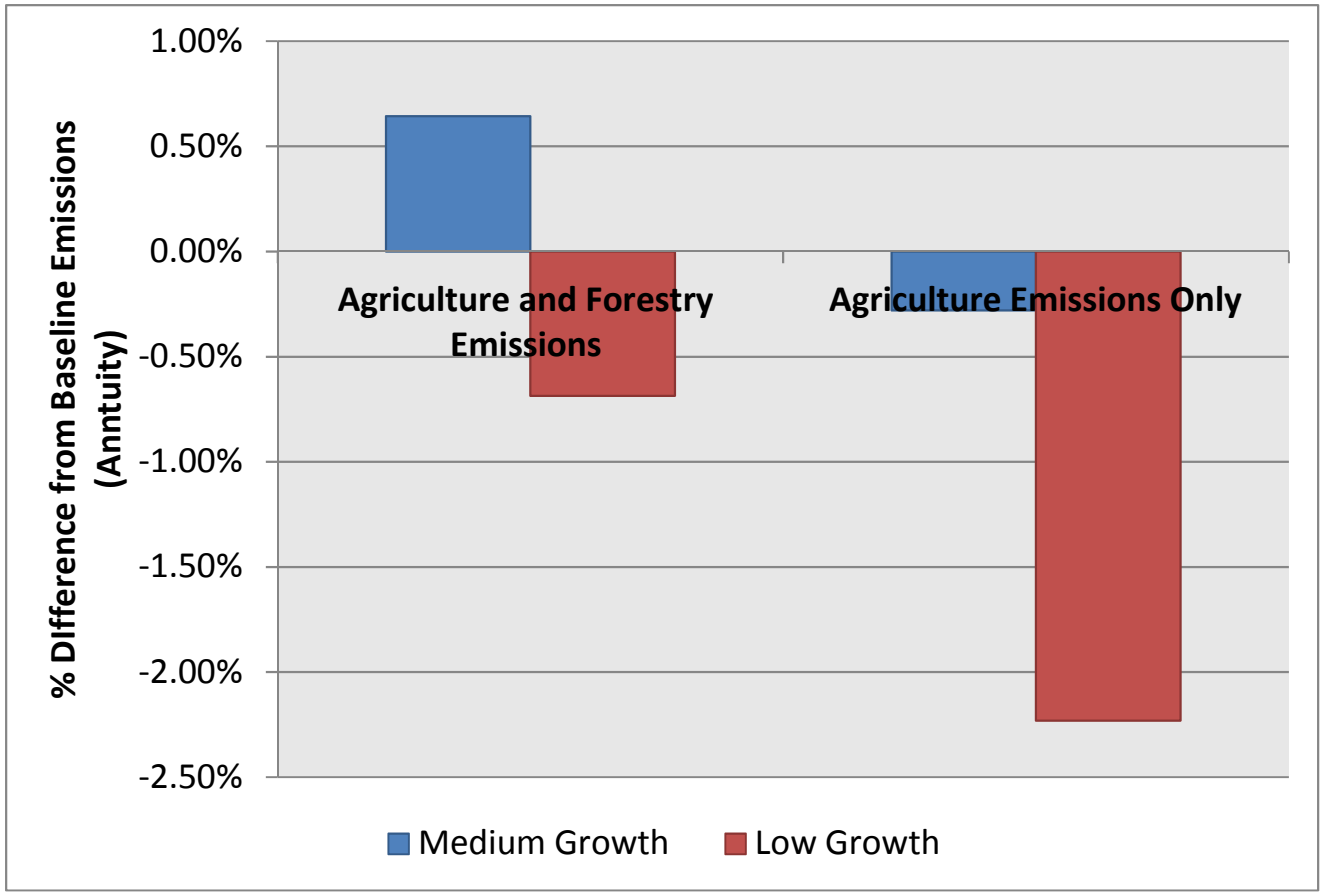
Net Agricultural Emissions



- Very little difference in agricultural emissions across scenarios

Difference in Net Emissions



- With forestry sector emissions included, less than *1% difference* in aggregate emissions across scenarios
- Total emissions from agriculture actually ***decline*** slightly with lower productivity

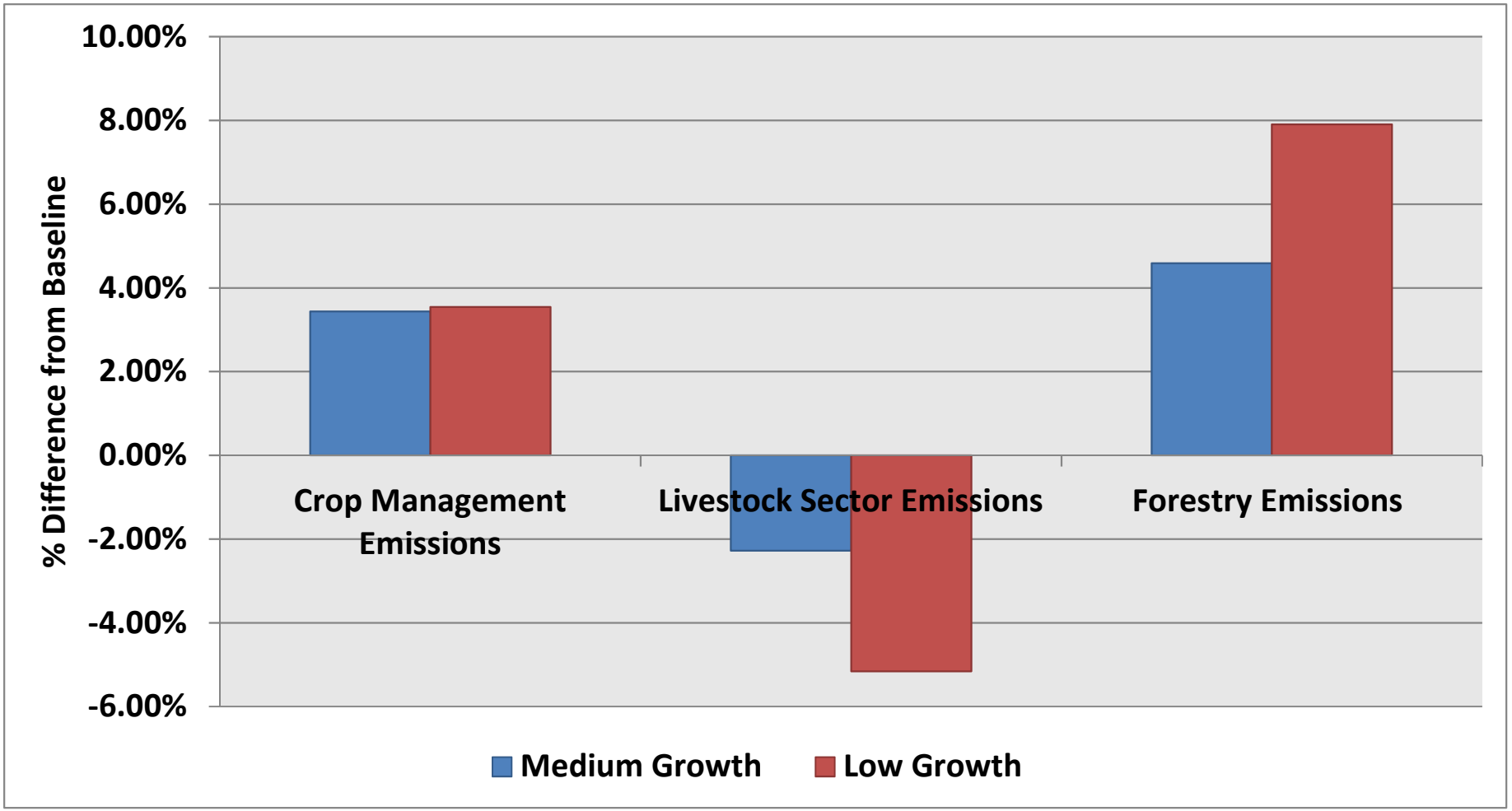
Why are Emissions Trajectories so Similar?

- It's a balance of land use and production shifts between crops, livestock, and forestry

- Higher growth =>
  - lower N2O and fossil fuel emissions,
  - increased agricultural soil carbon accumulation, but
    - Higher methane emissions from intensive livestock operations

- Lower growth =>
  - Higher net emissions from crop production
  - Lower net emissions from livestock sector
  - Greater forest carbon stock
    - Lower rents drive some land into forestry

Difference in Aggregate Emissions



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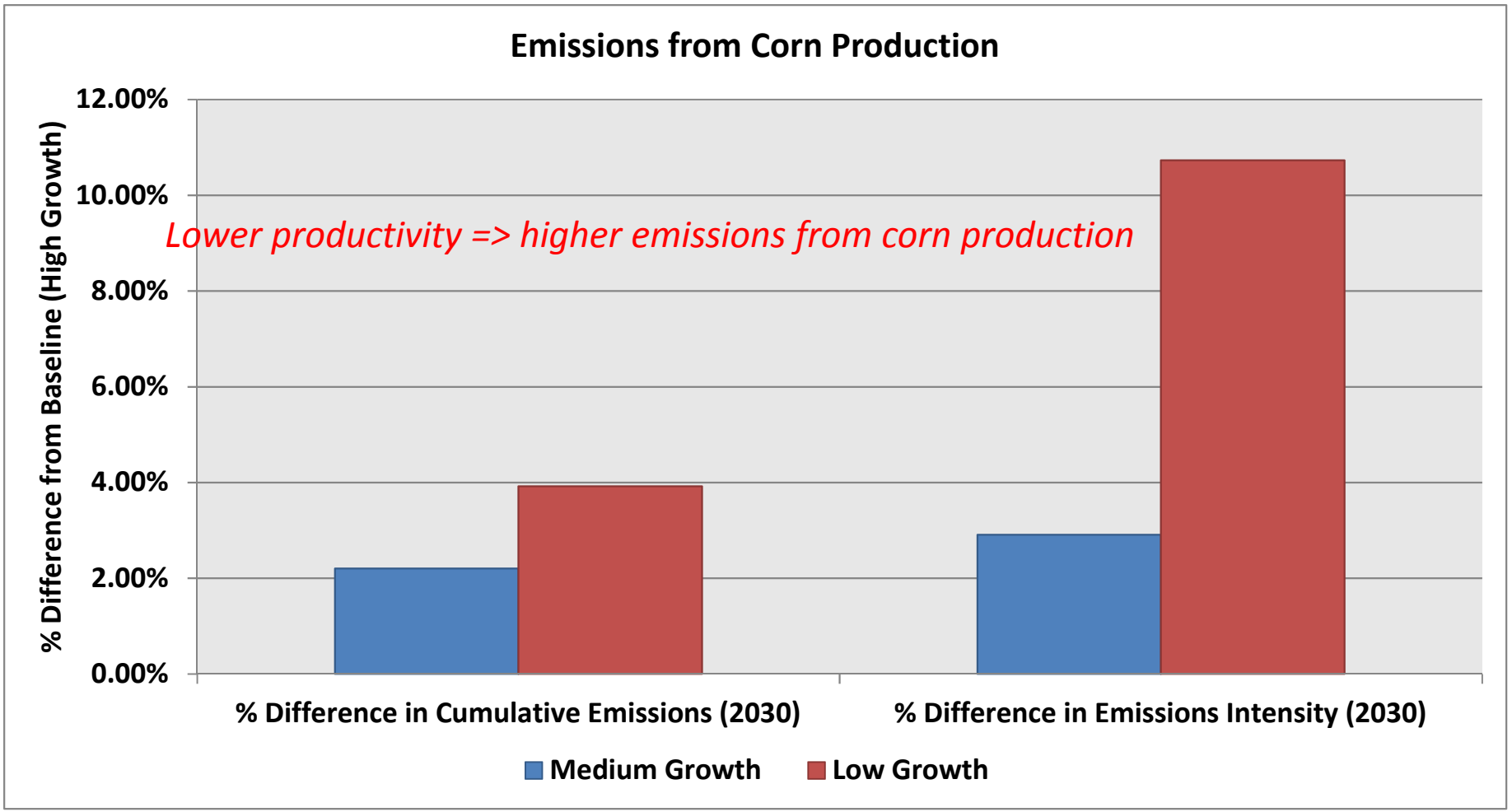
GHG Emissions from U.S. Corn Production



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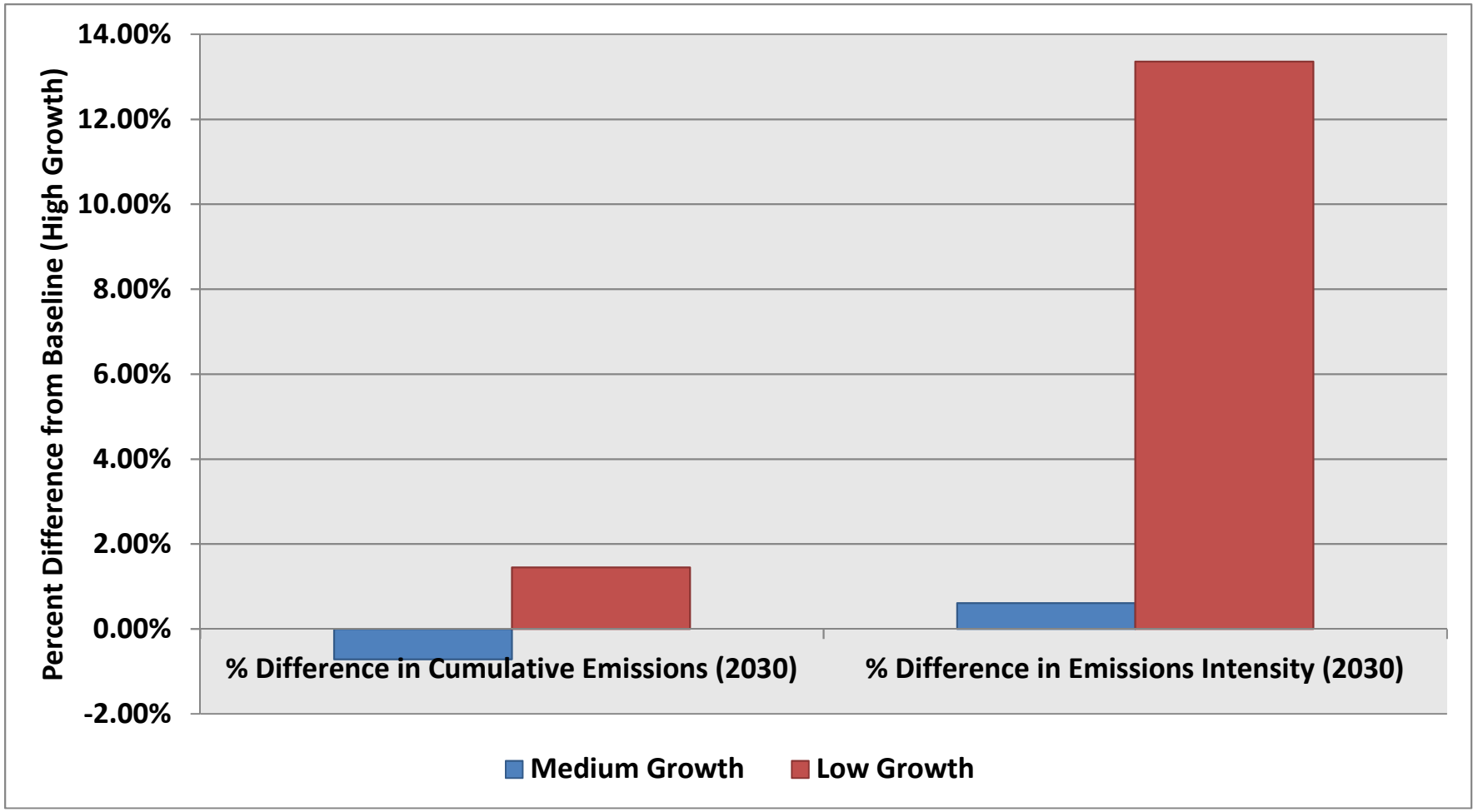
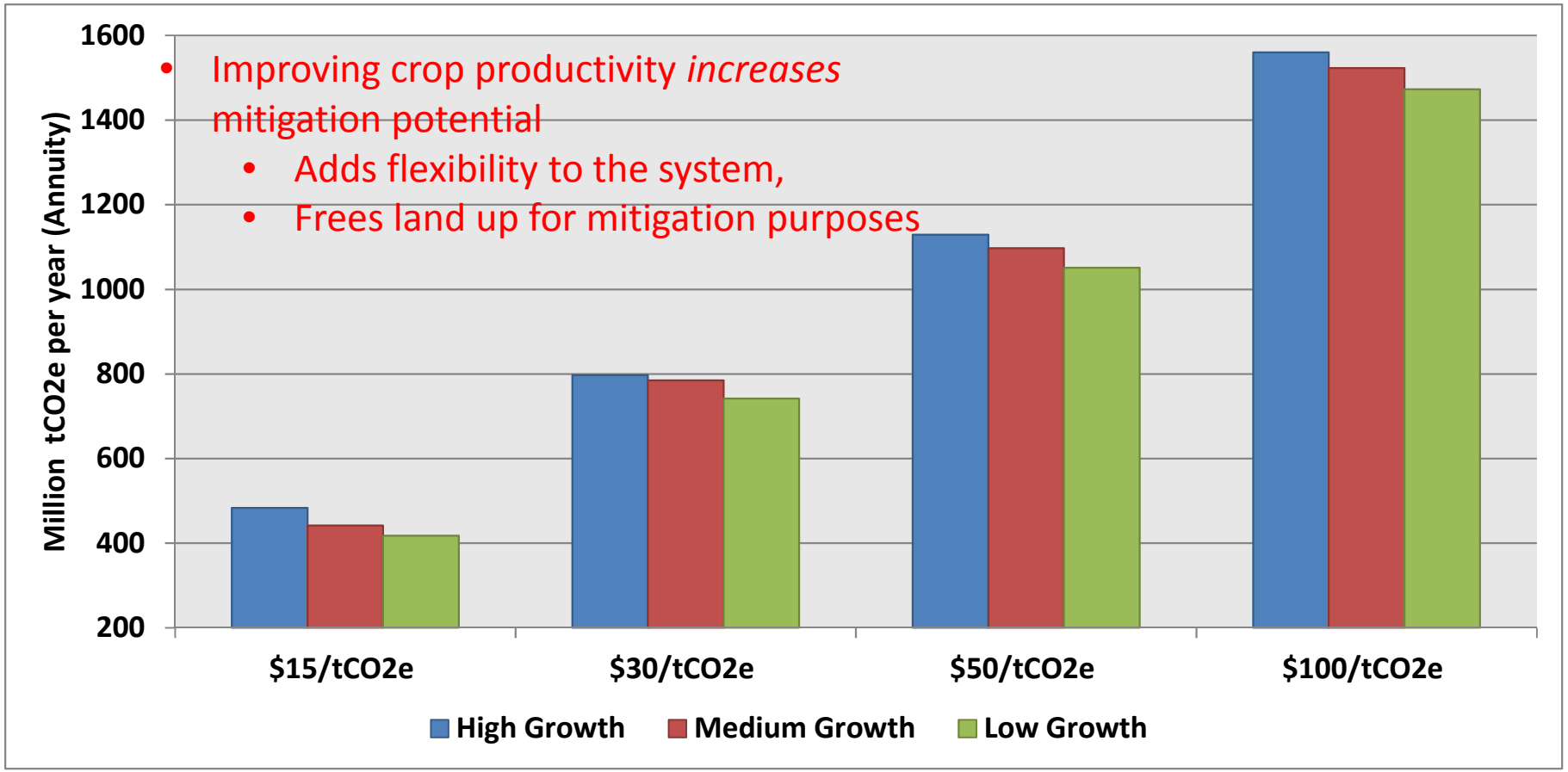
GHG Emissions from U.S. Wheat Production

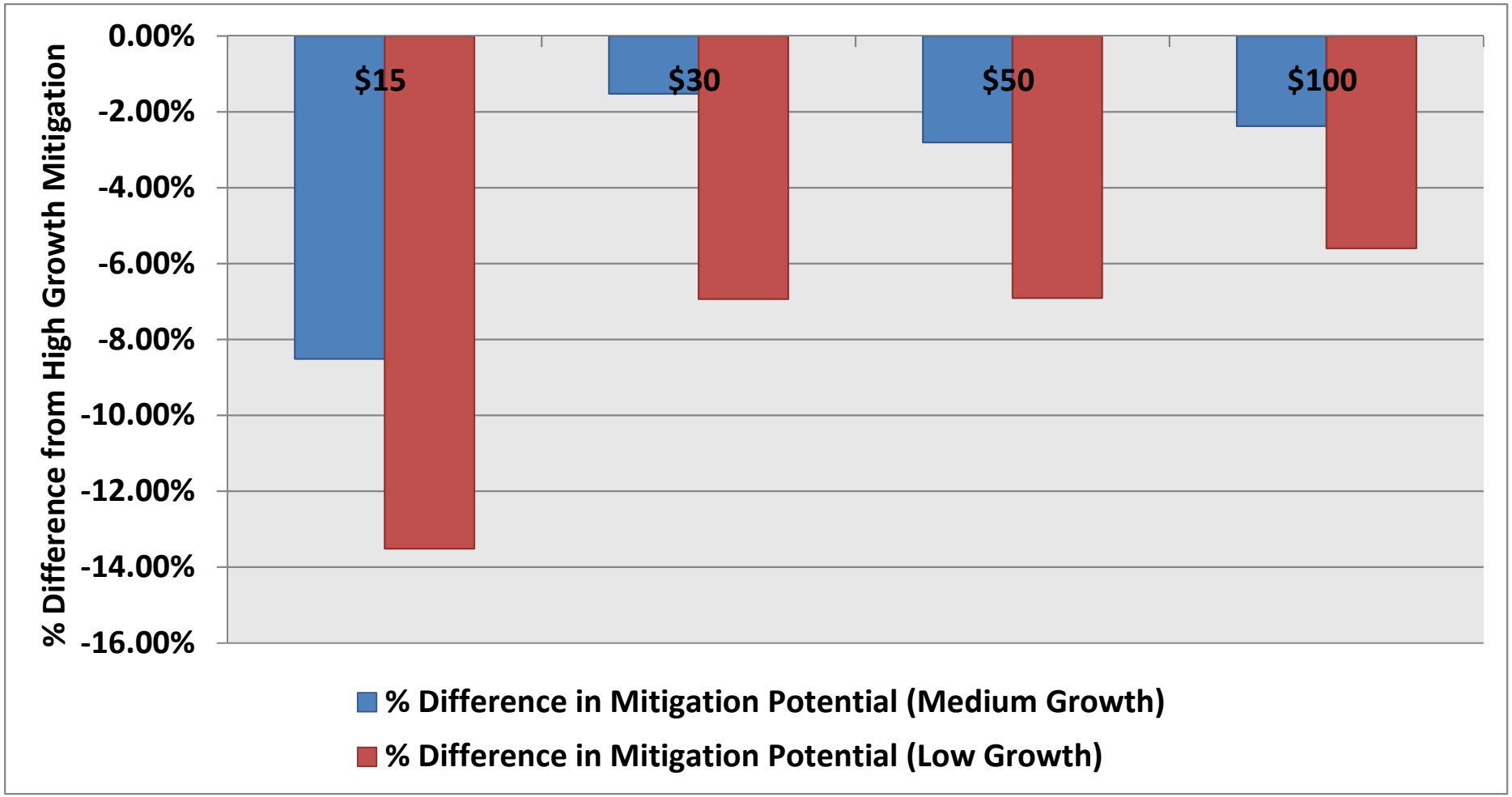


Comparing Mitigation Potential across Productivity Scenarios

- Improving crop productivity *increases* mitigation potential
  - Adds flexibility to the system,
  - Frees land up for mitigation purposes



Difference in Mitigation Potential by CO_2 Price (Offsets + Bioenergy)



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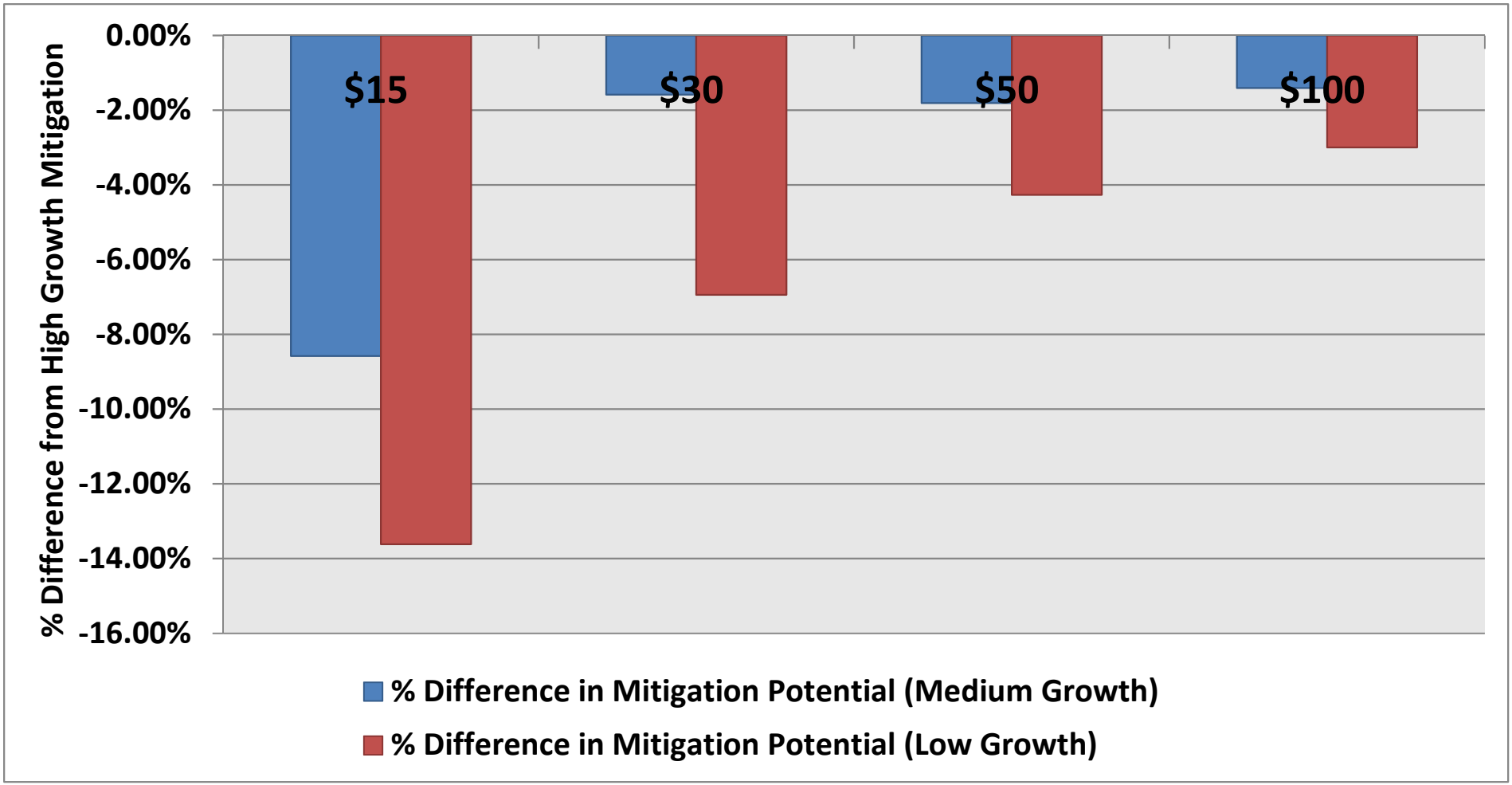
Difference in Mitigation Potential by CO_2 Price (Offsets Only)



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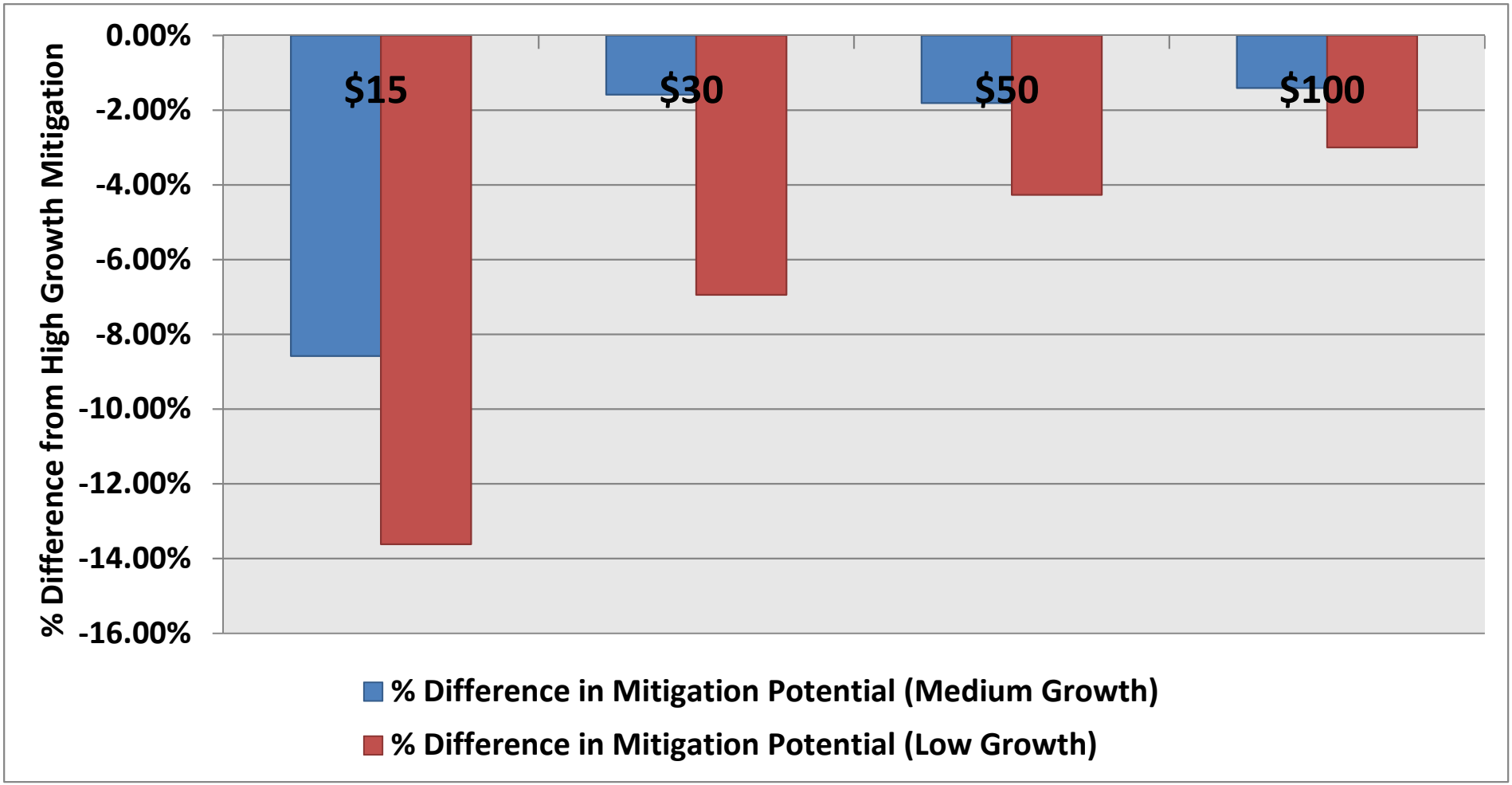

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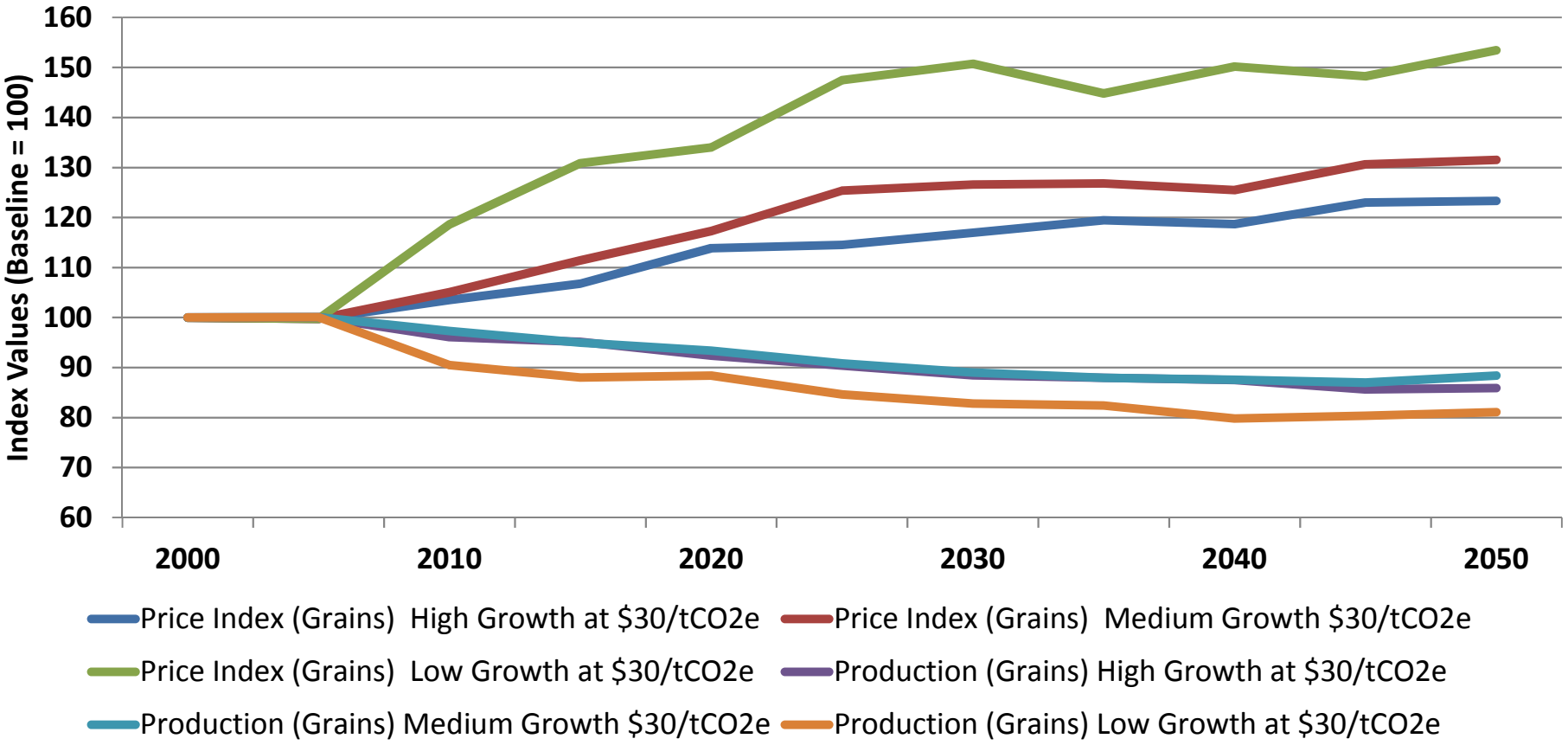
Production and Price Effects (evaluated at $30/tCO2e)



- *Production and price responses alleviated by higher productivity*
- *Implies reduced leakage risk*

Preliminary. Do not cite.

Summary of Simulation Analysis

- Lower agricultural productivity pushes land to the ***intensive*** and ***extensive*** margin
  - Lowers total production
  - Can lead to environmental quality degradation

- Baseline emissions do not change significantly across scenarios
  - Higher crop productivity increases emissions from livestock operations
  - Important to consider full suite of emissions

- However, GHG mitigation is more cost effective under higher productivity regimes
  - Frees up land for carbon sequestration and bioenergy
  - Difference is greatest at lower CO_2 prices
  - Reduces leakage risk

General Conclusions

- Exogenous productivity shifts can have an ambiguous net impact on net emissions
- If coupled with mitigation incentives, productivity growth can improve abatement potential
  - Convergence at high price incentives?
- Policy efforts should encourage agricultural technological growth and GHG mitigation conjunctively
  - However, productivity growth is not a panacea

Thank you

- Further questions:
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