On Climate and Economic Analysis

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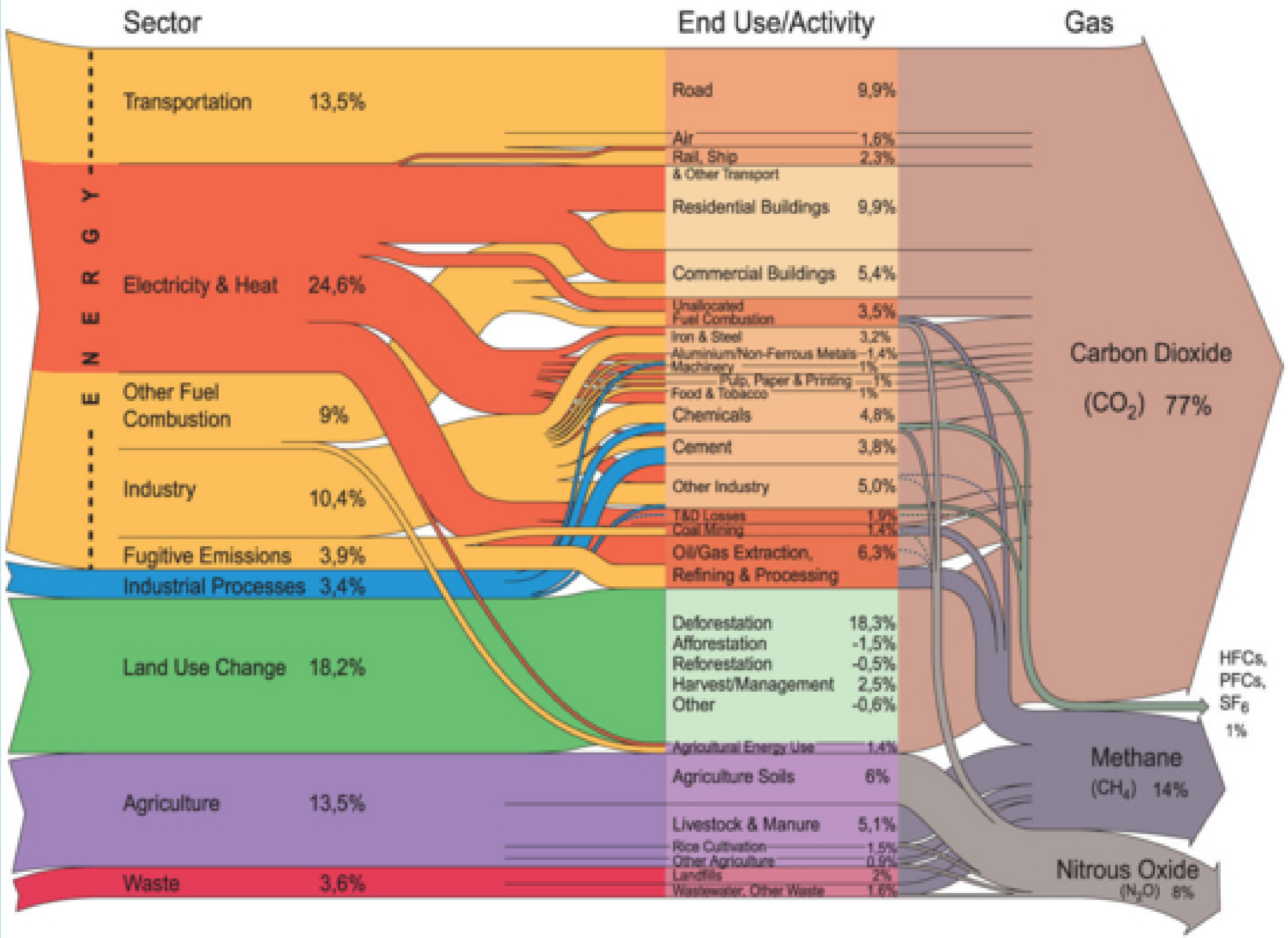
Climate and Agriculture

- Rising carbon dioxide levels have effects on crop yields
- Both detrimental and beneficial
- The overall effect of climate change on agriculture will depend on the balance of these effects

On one hand

- Agricultural production is responsible for the release of greenhouse gases such as carbon dioxide, methane, and nitrous oxide
- Altering the earth's land cover, which can change its ability to absorb or reflect heat and light, and contributing to radiative forcing
- Land use change - deforestation and desertification, together with use of fossil fuels, are the major anthropogenic sources of carbon dioxide
- Agriculture itself is a contributor to increasing methane and nitrous oxide

World Greenhouse gas emissions by sector



All data is for 2000. All calculations are based on CO_2 equivalents, using 100-year global warming potentials from the IPCC (1996), based on a total global estimate of 41 755 $MtCO_2$ equivalent. Land use change includes both emissions and absorptions. Dotted lines represent flows of less than 0.1% percent of total GHG emissions.

Source: World Resources Institute, Climate Analysis Indicator Tool (CAIT), Navigating the Numbers: Greenhouse Gas Data and International Climate Policy, December 2005; Intergovernmental Panel on Climate Change, 1996 (data for 2000).

On the other hand

- Food production is very sensitive to weather and climate change
- Temperature affects production
- Water resources
- Changes in rainfall
- Extreme events
- The impact depends on “carbon fertilisation”

- Carbon dioxide is a building block for plant growth
- Higher concentration may enhance plant growth
- These benefits may actually larger than the cost?
- Depends on crops and agroecological zones
- **Threshold**

In some areas

- Wheat and Rice will increase for 2 degrees increase
- Then fall when increase is larger
- Corn shows larger decline
- Decline of food production is likely to leave millions of people without the ability to access sufficient food

- Countries with greater wealth and natural resource endowments adapt more efficiently than those with less

Most vulnerable regions: Africa, Asian mega-deltas, small islands, the Arctic

Most vulnerable sectors:

- water in the dry tropics
- agriculture in low latitudes
- human health in poor countries
- Where activities depend on sensitive ecosystems, especially:
- tundra, boreal, mountains or ecosystems already stressed

Mendelsohn et al. 2006

- The impact of climate change on rich and poor countries across the world.
- Developing countries were predicted to be more vulnerable because so much of their economies were in climate-sensitive sectors + low technology operations are expected to have less substitution (Fankhauser, 1995; Tol, 1995).
- Assumed that almost every region would be damaged by warming

Several climate-sensitive sectors have a hill-shaped relationship with absolute temperature

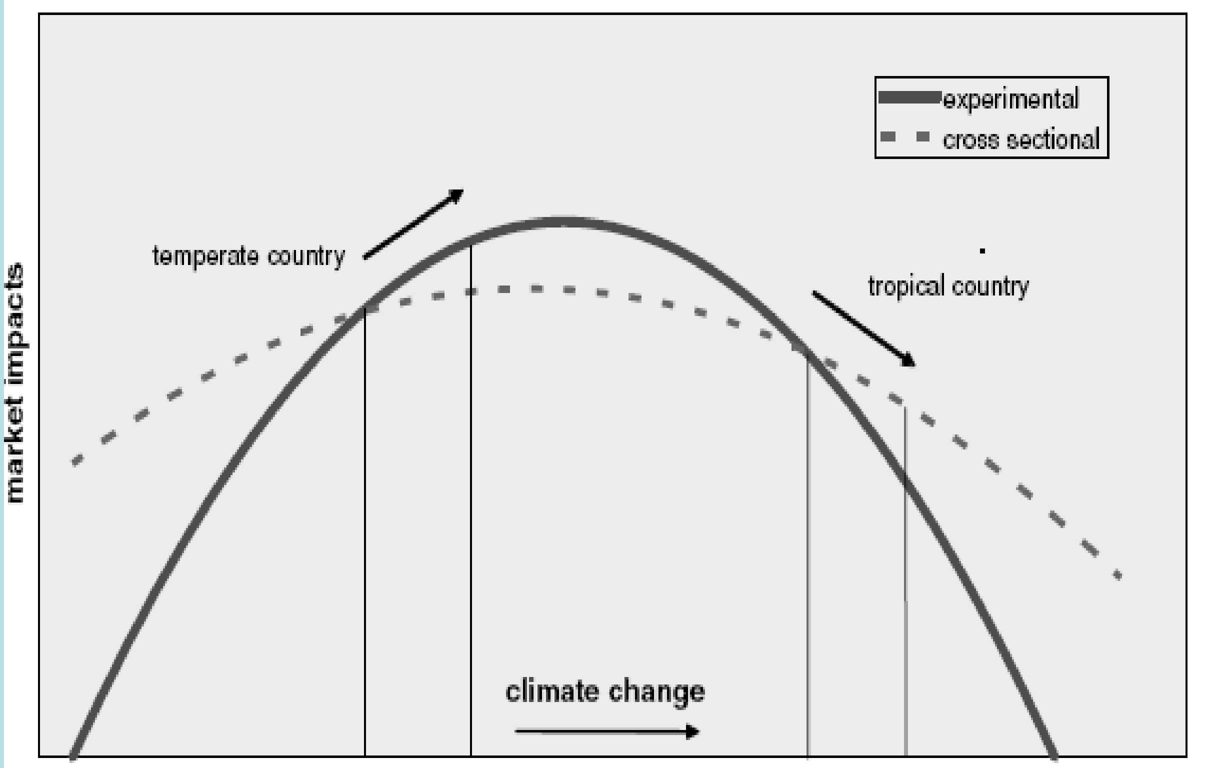


Figure 1. *Generic hill-shaped impact response function*

Location, location, location!

- Countries in the low latitudes start with very high temperatures
- Further warming pushes these countries ever further away from optimal temperatures for climate sensitive economic sectors

The Role Economic Analysis

1. Food Production and Security
2. Probability of adaptation by farmers
3. Risk management
4. The role of 2 on 1. and 3.

Economic and Climate Data: some issues

- Aggregation
- Data frequency
- Spatial Definition
- Availability of Panel Data
- Time span to implement dynamic analysis

Estimating the impact of Climate Change

- Production function approach
- Estimating a production technology
- Conversion of inputs into output
- Simple and convenient mathematical representation
- Extended version with climate variables
- Estimation of the parameters
- Ricardian approach

Adaptation

- Changing crops or using biodiversity – quite low cost
- Changing planting dates
- Irrigation both small and large scale
- Soil conservation practices
- New cultivars and genetic improvement
- GMO (?)
- Migration to urban areas
- Financial instruments

Documenting Rainfall Shocks, Biodiversity and Resilience

From Di Falco and Chavas 2008

Adaptation through changing crop or crop mix implies taking advantage of biodiversity to manage climatic change

Biodiversity

- Convention on Biological Diversity at the UNCED conference in Rio de Janeiro in 1992
- The number, variety and variability of all living organisms in terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part
- It is evident from this definition that biodiversity is intended to capture two dimensions:

1. The number of biological organisms
2. Their variability

Biodiversity and the provision of environmental services

- Life support services: diverse ecological systems facilitate environmental functions, such as carbon cycling, soil fertility maintenance, climate and surface temperature regulation, and watershed flows.
- The diversity of flora and fauna in ecosystems contributes to the amenity services that we derive from the environment.
- Also in relation to inputs to production, those flora and fauna are the source of many useful products, particularly pharmaceuticals, foods and fibres;
- The genes that they contain also constitute the materials on which future developments in biotechnology will depend
- In terms of agriculture, biodiversity is the basis for crop and livestock variability and the development of new varieties

- Diverse gene pools represent a form of insurance against ecological collapse; the greater is the extent of diversity, the greater is the capacity for adaptation to stresses and the maintenance of the ecosystem's organisational and functional structure

- **Diversity and Resilience**
- **Resilience its an important indication of sustainability**

An example from the Mediterranean Area

- Recent weather trends show an increase in average temperature and more erratic rainfall patterns
- Some areas of the planet have become drier (desertification)
- Annual precipitation trends in southern Europe showed a reduction in annual rainfall up to 20%
- Projections forecast a further decrease between 5% and 15% over the next decade

(EEA Report No 2/2004; IPCC WGII report, 2003; Hulme et al., 1999; Parry, 2000)

- The reduction of rainfall can have implications of paramount importance for managed ecosystems such as agroecosystems
- Lower rainfall $\longrightarrow$ environmental stress
- Capability of the system to retain organizational structure and maintain productivity (Holling Resilience)
- Holling resilience if is able to maintain productivity and withstand stress or external shocks (e.g., due to lower rainfall and droughts)

- In many situations, biodiversity provides the link between stress and loss of resilience is a system (Perrings et al. 1995)
- Genetic variation - within and across crop species - increases the ability to respond to the challenges of environmental stress (Mainwaring, 2001)
- Biodiversity ensures that whatever the environmental conditions, there will be plants that thrive under those conditions (Heal, 2000)
- Growing functionally similar plants that respond differently to weather and temperature randomness contributes to resilience (Holling, 1973)

Evidence

- Plant biomass is an increasing function of diversity (Tilman and Downing, 1994; Naem et al., 1995; Lehman and Tilman, 2000; Tilman et al., 1996),
- Higher diversity contributing to increases in the productivity of ecosystems (Tilman et al., 2005)

One explanation..

“Multiple species coexistence occurs if there is an interspecific tradeoff such that each species is a superior competitor for a limited range of values of the physical factor, and if the physical factor is heterogeneous” (Tilman et al., 2005)

We need…

1. To provide an analysis of the dynamic contribution of inter-specific crop biodiversity to the productivity of cereal agro-ecosystems by biodiversity using dynamic panel data
2. To investigates the role of biodiversity and its interaction effects with rainfall in the dynamic analysis of productivity
3. To develop the implications of the econometric estimates by a set of simulations

Framework

$$y_{it} = f_{it}(x_{it}, \cdot)$$

where y = quantity of cereals produced

x = is a vector of inputs; (e.g., land, labour, capital, and fertilizer) along with rainfall and crop biodiversity

$\cdot$ = denotes other factors

- $f_{it}(x_{it}; y_{i,t-1}, .., y_{i,t-p}, x_{i,t-1}, .., x_{i,t-q})$ for some $p \geq 0$, $q \geq 0$

- $\ln(y_{it}) = A(_{i,\ t}) + \alpha \ln(x_{it}) + \sum \beta k \ln(y_{i,t-k}) + \sum \gamma k \ln(_{xi,t-k})$

- $\ln(y_{it}) = A + \alpha \ln(x_{it}) + \sum \beta k \ln(y_{i,t-k}) + \sum \gamma k \ln(x_{i,t-k}) + \delta_0 \ln(\text{biodiversity}_t) \ln(\text{rainfall}_t) + \delta_1 \ln(\text{biodiversity}_t) \ln(\text{rainfall}_{t-1}) + \mu_i + v_{it}$

Site, Data and Variables

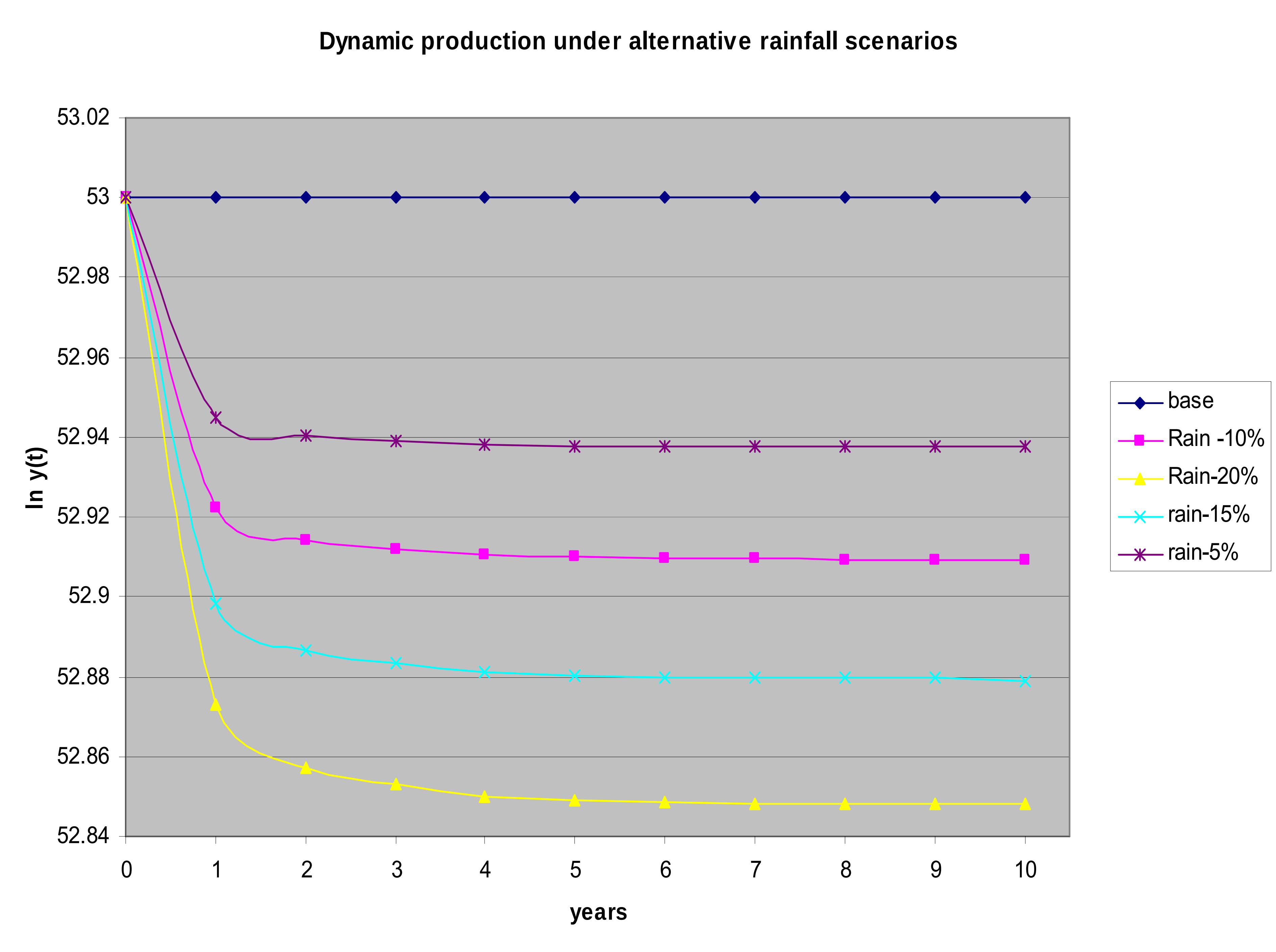
- Eight regions in Southern Italy
- Megadiversity spot for cereals
- Rainfed production environment
- 1970 - 1993
- All the eight regions under the same institutional framework (objective one of the Common Agricultural Policy)
- Conventional inputs: fertilizer, land, capital, labor – along with rain
- Interaction between rainfall and biodiversity
- GMM estimation

Variables	*Arellano Bond GMM estimation (A)*	*Arellano Bond GMM estimation (B)*
y_{t-1}	0.12(0.2)	0.129 (0.18)
y_{t-2}	0.12* (0.07)	0.156* (0.08)
Biodiversity$_t$	10.4*** (3.82)	9.87***(3.65)
Biodiversity$_{t-1}$	4.24* (2.5)	3.94* (2.4)
Bio$_t$ * **rain**$_t$	-1.5*** (0.56)	-1.4*** (0.53)
Bio$_t$ * **rain**$_{t-1}$	-0.41** (0.2)	-0.35*(0.2)
Land$_t$	2.82*** (1.1)	3.02*** (1.2)
Land$_{t-1}$	-1.36* (0.8)	-1.2* (0.7)
Labor$_t$	1.18* (0.7)	1.07* (0.62)
Labor$_{t-1}$	-0.38 (0.5)	-0.5[a] (0.4)
Fertilizer$_t$	1.18*** (0.29)	1.17*** (0.36)
Fertilizer$_{t-1}$	0.14 (0.2)	-
Capital$_t$	1.41***(0.67)	1.38**(0.61)
Capital$_{t-1}$	-0.184*** (0.7)	-
Rain$_t$	0.06 (0.15)	0.248(0.36)
Constant	0.43 (0.99)	0.0145(0.071)

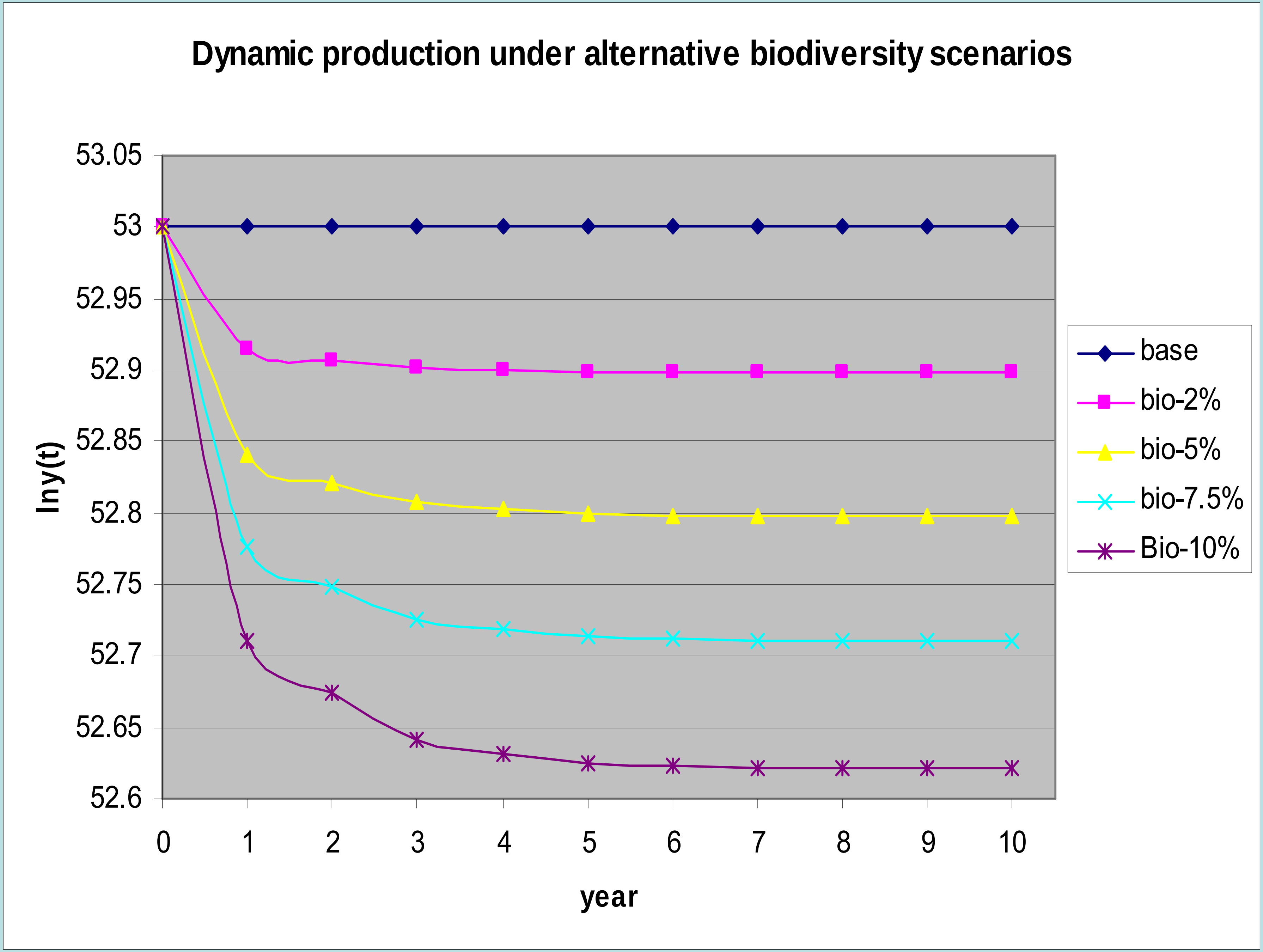
- The elasticity of production with respect to crop biodiversity is 0.87 in the short run, and 3.29 in the long run
- The interaction effects in the model imply that the role of biodiversity varies with rainfall
- Consider the production elasticity with respect to crop biodiversity when rainfall is 20 percent below the sample mean
- <u>Elasticity increases from 0.87 to 1.14 in the short run, and from 3.29 to 3.75 in the long run</u>
- This shows that the productivity benefits of biodiversity are larger when rainfall declines and the ecosystem faces environmental stress

What is impact of biodiversity, rainfall shocks and their interaction on production?

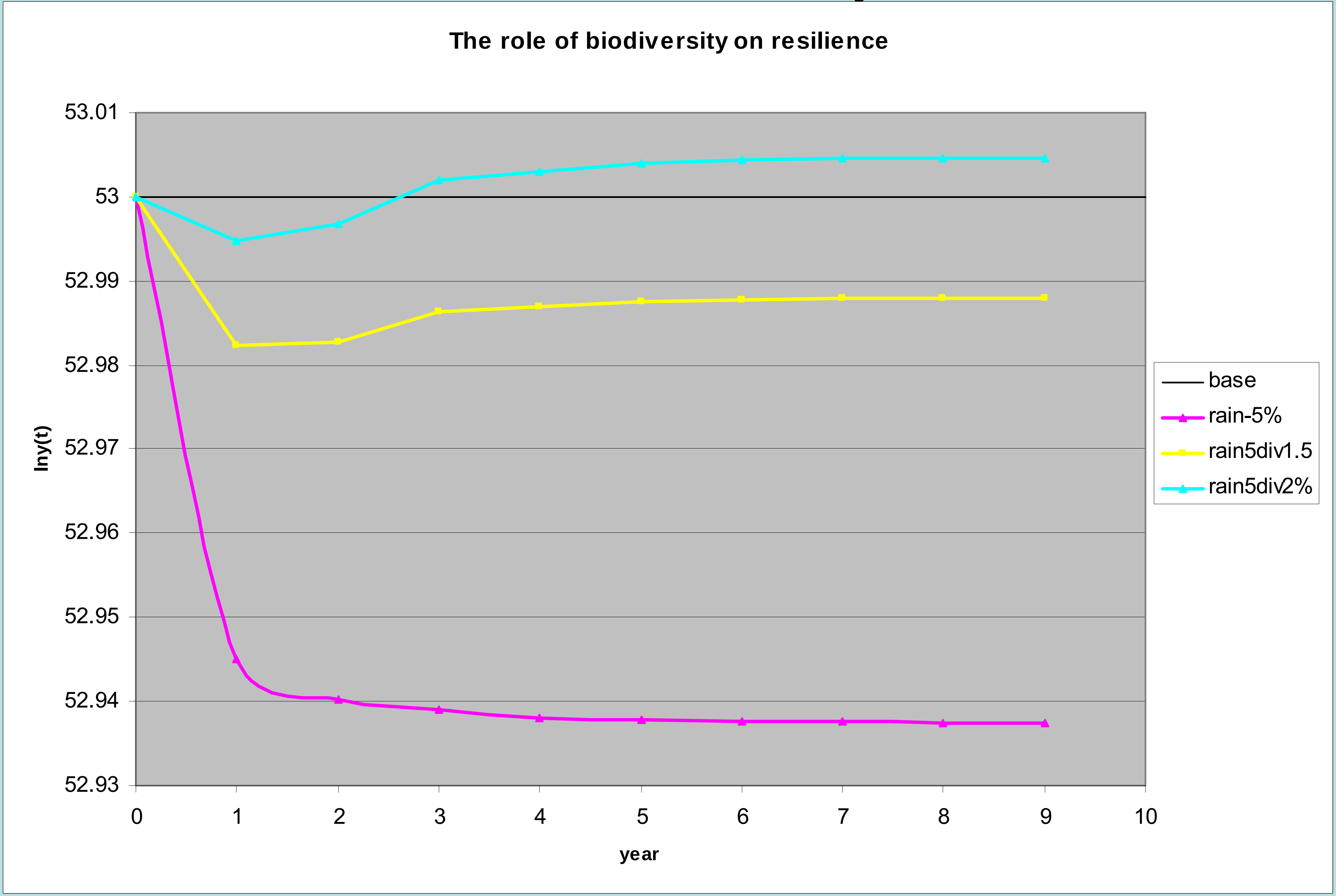
- The estimated model is used to simulate production under alternative scenarios
- Start with a base scenario where the agroecosystem production is simulated forward in time
- The comparison of these paths across scenarios provides useful insights into resilience and agroecosystem dynamics
- IPCC estimated rainfall reduction is 5% to 15%



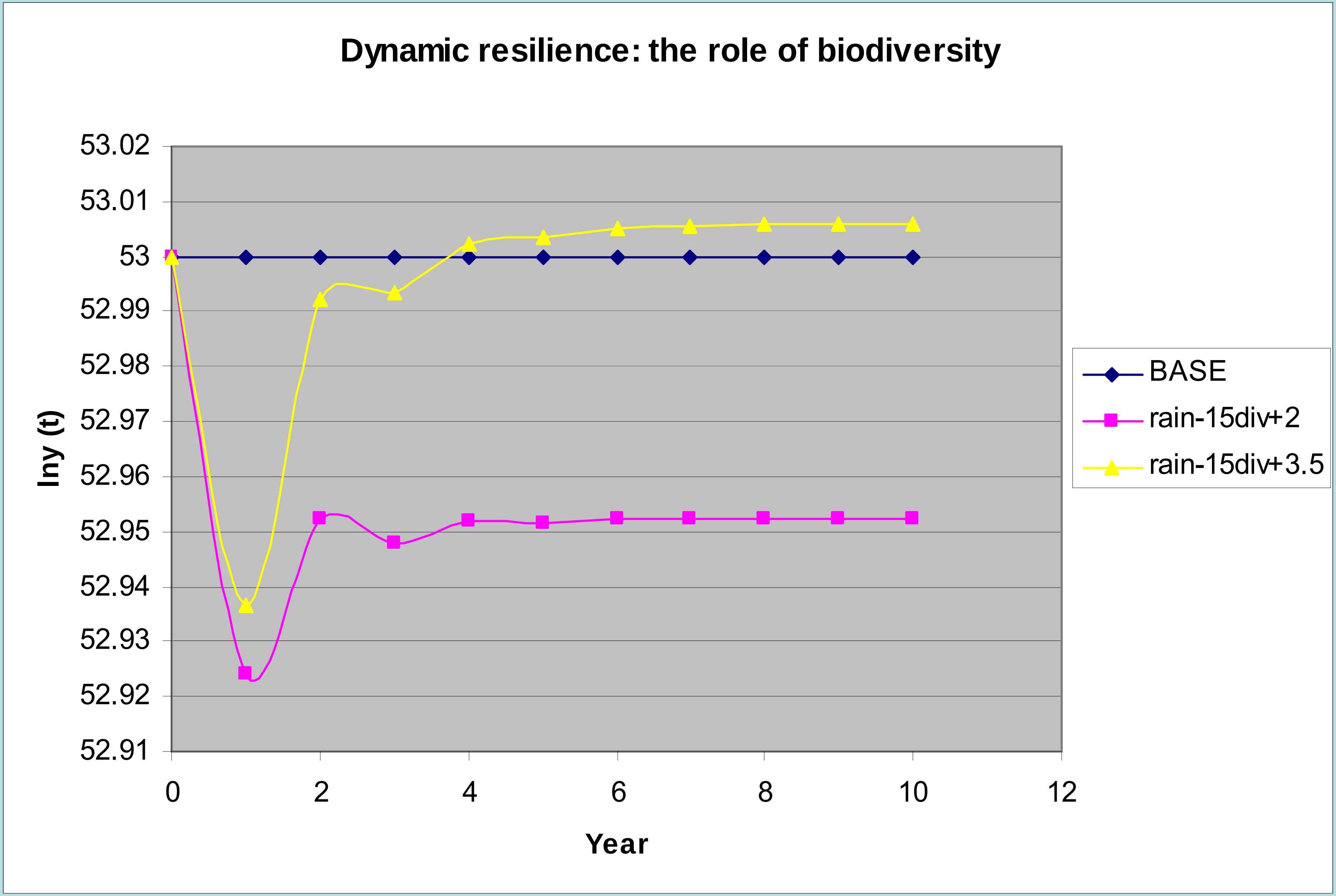
Dynamic production under alternative rainfall scenarios
53.02
53
52.98
52.96
52.94
52.92
52.9
52.88
52.86
52.84
ln y(t)
0
1
2
3
4
5
6
7
8
9
10
years
base
Rain -10%
Rain-20%
rain-15%
rain-5%


Dynamic production under alternative biodiversity scenarios
lny(t)
53.05
53
52.95
52.9
52.85
52.8
52.75
52.7
52.65
52.6
0
1
2
3
4
5
6
7
8
9
10
year
base
bio-2%
bio-5%
bio-7.5%
Bio-10%

What can biodiversity do?



What can biodiversity do?...Under harsher conditions



When Spatial Data Are Available

- Joint work with Mahmud Yesuf, Claudia Ringler and Gunnar Kohlin
- The Nile basin (Ethiopia)
- 1000 farms producing *cereal* crops
- *M*onthly collected meteorological station data + the Thin Plate Spline method of spatial interpolation is used to impute the household specific rainfall and temperature values of each household.
- The rainfall data is disaggregated at season level (*Mehere* and *Belg*)

Two Stages approach

- Assess the probability of adaptation
- Feed this information in a production model
- Information on the characteristics of the farmers who adapt
- If adaptation delivers a payoff in terms of yields

$$A_{hi} = A(x_{hi}^{h}, x_{hi}^{l}, x_{hi}^{c}; \beta) + \varepsilon_{hi}$$

$$y_{hi} = f(x_{hi}^{s}, x_{hi}^{c}, A_{hi}, \gamma) + \xi_{hi}$$

Results

Variables	Change in crops (1) Coefficients	Std errors	Tree planting (2) Coefficients	Std errors	Soil conservation (2) Coefficients	Std errors
Access to formal credit	0.474***	0.1	0.211***	0.088	0.12	0.101
Farmer to farmer extension	0.54***	0.155	0.0693	0.113	0.153	0.12
Access to formal extension	0.681***	0.179	0.03035	0.1154	0.923***	0.179
Education	0.061***	0.025	0.01268	0.0167	0.038**	0.018
Gender	0.456*	0.28	0.486**	0.227	0.197	0.139
Marital status	0.35***	0.12	0.471***	0.125	0.153***	0.0571
Household size	0.058**	0.024	0.05***	0.01	0.059**	0.0259
Age	-0.0065	0.004857	-0.007*	0.0039	0.013***	0.0045
Relative	0.0126***	0.0028	0.0102***	0.002	-0.007**	0.0037
Belg (short rain season)	0.65***	0.122	0.908***	0.099	0.33***	0.111
Meher (Long rain season)	-1.245***	0.245	1.535***	0.19	-1.3***	0.23
Temperature dispersion	0.057908	0.2652	-1.24***	0.251	1.06***	0.25
Information on climate change	0.14021	0.128	0.44***	0.111	0.28***	0.119
Soil fertility	-0.04546	0.076	-0.096	0.065	-0.0888	0.0712
Dummy for Agroecology	-0.08874	0.182	0.257	0.182	0.353**	0.156
Dummy for Agroecology	0.204*	0.1245	0.914***	0.135	0.739***	0.113
Constant	-4.7917	1.292	-7.8***	1.15	-8.378***	1.39

Production impact

Variables	Coeffs	Std Errors
Prediction 1	620.9***	164.5
Prediction 2	592.2***	174.7
Prediction3	50.98	36.3
Temperature dispersion	-143.033	168.3
Belg (short rain season)	156.79**	78.3
Meher (Long rain season)	-323.32***	135.2
Soil fertility	96.01***	31.9
Labour	3.12***	0.79
Fertilizer	0.398	0.34
Manure	0.086	0.077
Seeds	2.345***	0.42
Labou^2	-0.00084	0.0012
Fertilizer^2	-3.84E-06	9.49E-06
Manure^2	-0.00011	0.0004
Seeds^2	0.000385	0.00038
Dummy for Agroecology	-351.138***	123.29
Dummy for Agroecology	-557.051***	60.11
Constant	2424.2***	743.28

Conclusion

- Economic models can provide useful information the implication of climate change in agriculture
- Both static and dynamic
- Data nature from different fields
- Data availability and frequency in the different field

Thank you

Comments very welcome

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The Ricardian Approach

- Dumb farmer scenario…
- People make adjusment to changing environmental conditions
- Switch crops
- Activities
- There is always another possibility
- Production framework does not capture that

Mendelsohn et al.

- **By not permitting a complete range of adjustments, previous studies have overestimated damages from environmental changes.**
- **Only wheat: peaking at point B, then falling as temperatures rise too high.**
- **A production-function approach would esti- mate the value of wheat production at dif- ferent temperatures along this curve.**
- **The bias in the production-function ap- proach arises because it fails to allow for economic substitution as conditions change**

Alternative

- To examine how climate in different places affects the net rent or value of farmland.
- By measuring farm prices or revenues
- This accounts for the direct impacts of climate on yields of different crops as well as the indirect substitution of different inputs, introduction of different activities, and other potential adaptations to different climate

Assumption

- **If <u>markets are functioning properly</u>, the Ricardian approach will allow us to measure the economic value of different activities and therefore to verify whether the economic impacts implied by the production function approach are reproduced in the field**

- Existing pattern of land rents and prices reflecting the long run equilibrium economic effect of climate change

Regression model

- **Regress land values on climate, soil, and socioeconomic variables to estimate the best-value function across different counties.**
- **2,933 cross-sectional observations in the USA.**
- **The means have been removed from the independent variables in this regression**
- **The quadratic climate variables are consequently easier to interpret**

Ricardian Approach:

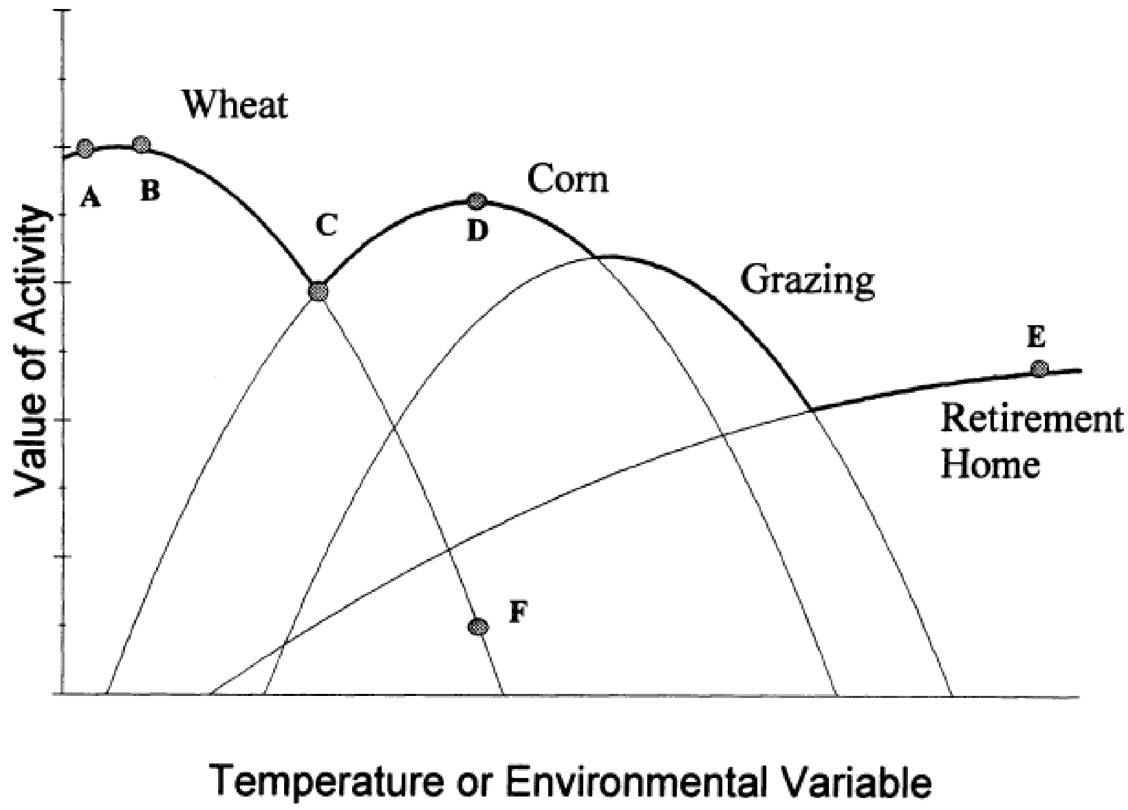

FIGURE 1. BIAS IN PRODUCTION-FUNCTION STUDIES

Findings

- **Higher temperatures in all seasons except autumn reduce average farm values**
- **More precipitation outside of autumn increases farm values**
- **A significantly lower estimated impact of global warming on U.S. agriculture than the traditional production-function approach and,**
- **In one case their finding suggests that, even without CO2 fertilization, global warming may have economic benefits for agriculture**