Bioeconomy - science and technology policy for agricultural development and food security

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On “New directions in the fight against hunger and malnutrition”
Cornell, Dec. 13th, 2013
Overview

1. Bioeconomy and Emerging Value Webs

2. The Drivers of Bioeconomy and Food Security Implications

3. Resetting Research Agendas for Agriculture and Food Security
Agriculture and Food System - redefined

From traditional agriculture: farms + forests + fish

To value chain: agri-business and retail revolution

To systems: ecosystems services

To linked value chains / webs: the bioeconomy

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From Commodities to Value Chains

Food and feeds

Grains
Flour
Feeds
Bread
Meat

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System challenges and competing goals

Zero Carbon Emissions

Bioeconomy

CO2

Sustainable Production

Biomass

Residues

Zero Waste

Products

Ecological Footprints

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The emerging “Bioeconomy“ calls for adaptation of value chain concept

**Definition:** Bioeconomy is the knowledge-based production and use of biological resources to provide products, processes and services in all economic sectors within the frame of a sustainable economic system.*

**Consequence:** lots of intersecting “value chains” lead to => “value web”

*Source: German Bioeconomy Council, 2013*
New: Inter-linked value chains forming bioeconomic value webs

Foods and feeds
- Grains
- Flour
- Feeds
- Bread
- Meat

Bio-Energy
- Grains
- Bioenergy

Biomass-based raw materials
- Grains
- Tubers
- Shrubs
- Herbs
- etc

Financial Market Products
- Grains
- Financial assets
- Profit taking

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The economics of value webs: Key issues

1. **Transactions costs** (incl. ICT network effects) in value webs (incl. related services)

2. **Changing opportunity costs** of natural resources, capital, and labor in whole webs

3. **Improved capturing of externalities** (+ / - ) in webs, incl. environmental footprints

4. **Web-efficiency**, rather than chain efficiency redefining comparative advantages

5. **Distributional effects** (e.g. for the poor) in webs (who gains?)

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The bioeconomy:
A large cluster of sector elements

• Agriculture
• Forestry
• Fisheries
• Aquaculture
• Food industry
• Chemical industry (partially)
• Pharmaceutical industry (partially)
• Cosmetic industry (partially)
• Pulp & Paper industry (partially)
• Textile industry (partially)
• Energy industry (partially)

Bio-based raw materials, new processes, and technologies cutting across sectors and penetrating the economy: not really a “sector”

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Biomass2Chemicals, Biorefineries, New chemical industries and products (e.g. succinic acid, ‘spirit of amber’ produced through the fermentation of glucose from renewable feedstock and purification of raw bio-based succinic acid, as basis for food and bio-plastics)
Some innovative bioeconomy products

- Bioplastics
- Lacto-bactarial tooth paste
- New sugar substitutes
- Biochem. washing at low temperatures
- Biobased synthetic spider fibers
- Biobased building materials
- Wood pellets for coal co-firing
- Biofuels based on straw etc.
- Biomaterials in car industry

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Bioeconomy applications - examples

- **Food & feed**
  +

- **Biofuels**: sugar-ethanol; dedicated lignocellulosic crops.

- **Fibres**: spread value chains, decrease water and fertilizer use, fibre quality

- **Oil crops**: enhance use of vegetable oils in industrial applications, different fatty acid profiles.

- **Nutraceuticals and medical applications**: contents of bioactive compounds; food crops with health benefits, biofortification, proteins, insulin, blood substitutes, etc.

- **Adaptation of crops to marginal growing conditions**: heat, cold, drought, salinity, low nutrients, concentration of toxic metals.

- **Bio-refinery sectors**: transforming biomass into a wide range of value-added products (chemicals, materials, food and feed) or energy (biofuels, heat or power)

- **Markets for “unused” biomass**: carbon markets and ecosystems services

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Causes: Three mega trends driving toward Bioeconomy

1. Changing prices and price expectations
2. Changing preferences
3. Changing technologies

...and responses:
1. Strategic policy changes (e.g. energy)
2. Science and technology initiatives
Bioeconomy changes the world food equation

Supply = Demand

Supply:
- Land (shortage, degradation)
- Water (scarcity)
- Productivity & technology
- Labor & farm structure
- Climate change

Demand:
- Population (growth)
- Income (growth, urbanization)
- Poverty and inequality
- Consumer behavior, waste
- Biomass uses (energy etc.)

Trade and Markets
- Supermarkets
- Protection
- Financial markets
- Food stocks

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Trend in global distribution of biomass

(Above ground biomass) Zhao, Running, Science, August 20, 2010
Valuation of bio-based products in the Bioeconomy

Synthetic, land-independent bio-materials

Biomass based on land and water

Biomass based on land and water

Staples / animal feeds

Foods and beverages

Bio-energy

Bio-chemicals

Source: Bioeconomy Council, Germany, 2010

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Which prices drive food prices in the bioeconomy?

- input prices
- land price
- labor wages
- water price (costs)
- energy price
- financial asset (commodities)

All these prices are more interlinked and impact in diverse ways on the poor

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Determinants of Price Spikes (monthly) differentiating fundamental and conditional factors

<table>
<thead>
<tr>
<th></th>
<th>Wheat</th>
<th>Maize</th>
<th>Soybean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Production shock (%)</strong></td>
<td>-2.776856***</td>
<td>-1.129283**</td>
<td>-0.405249**</td>
</tr>
<tr>
<td></td>
<td>(-3.211036)</td>
<td>(-2.229914)</td>
<td>(-2.444792)</td>
</tr>
<tr>
<td><strong>Speculation (1000 contracts)</strong></td>
<td>0.000387***</td>
<td>0.000086***</td>
<td>0.000136***</td>
</tr>
<tr>
<td></td>
<td>(3.437195)</td>
<td>(4.733456)</td>
<td>(3.659829)</td>
</tr>
<tr>
<td><strong>Beginning stock-to-use ratio</strong></td>
<td>-0.003248**</td>
<td>0.001607</td>
<td>0.00014</td>
</tr>
<tr>
<td></td>
<td>(-2.166377)</td>
<td>(1.111166)</td>
<td>(0.128126)</td>
</tr>
<tr>
<td><strong>Oil price spike (%)</strong></td>
<td>0.127718**</td>
<td>0.095783*</td>
<td>0.151436***</td>
</tr>
<tr>
<td></td>
<td>(2.132944)</td>
<td>(1.691988)</td>
<td>(2.983429)</td>
</tr>
<tr>
<td><strong>GDP shocks (%)</strong></td>
<td>2.547861**</td>
<td>1.830320*</td>
<td>1.617096*</td>
</tr>
<tr>
<td></td>
<td>(2.017428)</td>
<td>(1.674219)</td>
<td>(1.679729)</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>0.079867**</td>
<td>-0.043883</td>
<td>-0.01448</td>
</tr>
<tr>
<td></td>
<td>(2.272285)</td>
<td>(-1.543078)</td>
<td>(-0.700671)</td>
</tr>
<tr>
<td><strong>R²</strong></td>
<td></td>
<td>0.209832</td>
<td></td>
</tr>
<tr>
<td><strong>N</strong></td>
<td></td>
<td>137</td>
<td></td>
</tr>
</tbody>
</table>

Seemingly unrelated regression results on food price spikes (coefficients and z-values). ***p<0.01, **p<0.05, *p<0.10. Source: Tadesse, Algieri, Kalkuhl, von Braun (in Food Policy, 2013)

Speculation boosted spikes by 38% for Maize, 22% for Soy, 3% for Wheat in 2008.
Some future research questions around bioeconomy and food security

1. New economy-wide competitions for biomass: Adverse impacts on food security?

2. Complementarities in value chains: Enhanced economic efficiency and environmental sustainability?

3. How can risks of bioeconomy for food security be addressed by enhanced S&T investment
If biomass demand expansion increases volatility, added nutritional risks may result.

<table>
<thead>
<tr>
<th>Dependent variable : child underweight</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Log GDP (PPP/cap)</td>
<td>-4.408*</td>
</tr>
<tr>
<td></td>
<td>(2.605)</td>
</tr>
<tr>
<td>Improved Sanitation</td>
<td>-0.327***</td>
</tr>
<tr>
<td></td>
<td>(0.109)</td>
</tr>
<tr>
<td>Gender oriented policy (Fem./male school enr.)</td>
<td>-0.156***</td>
</tr>
<tr>
<td></td>
<td>(0.0710)</td>
</tr>
<tr>
<td>Food Price Volatility (CV of FPI)</td>
<td>9.904***</td>
</tr>
<tr>
<td></td>
<td>(1.490)</td>
</tr>
<tr>
<td>N</td>
<td>300</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.430</td>
</tr>
<tr>
<td>Number of countries</td>
<td>93</td>
</tr>
</tbody>
</table>

Data: 93 Low and middle income countries, World Bank development indicators: GDP, Sanitation, Underweight. ILO: Food price indices 1990 - 2012, 2737 observations significant at *** 1%, ** 5%, * 10% level; country fixed effects included.

Source: Kalkuhl et al. 2013 (ZEF)
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# Bioeconomy Age:
## New science and policy initiatives 2007-13

<table>
<thead>
<tr>
<th>Country</th>
<th>Initiative/Strategic Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Bioenergy – Strategic Plan 2012–2015</td>
</tr>
<tr>
<td>Brasil</td>
<td>Biotechnology Development Policy (2007)</td>
</tr>
<tr>
<td>Danmark</td>
<td>Agreement on Green Growth (2009)</td>
</tr>
<tr>
<td>Germany</td>
<td>Nationale Forschungsstrategie BioÖkonomie 2030 (2010)</td>
</tr>
<tr>
<td>EU-Commission</td>
<td>A Bioeconomy for Europe (2012)</td>
</tr>
<tr>
<td>Ireland</td>
<td>Delivering our Green Potential (2012)</td>
</tr>
<tr>
<td>Canada</td>
<td>Biorefining Conversions Network (2009)</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Bioeconomy Initiative and National Biomass Strategy (2011)</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Biobased Economy 2010–2015</td>
</tr>
<tr>
<td>Russia</td>
<td>Bioindustry and Bioresources – BioTech 2030 (2012)</td>
</tr>
<tr>
<td>Sweden</td>
<td>Research and Innovation Strategy for Bio-based Econ. (2011)</td>
</tr>
<tr>
<td>UK</td>
<td>UK Bioenergy Strategy (2011)</td>
</tr>
<tr>
<td>USA</td>
<td>National Bioeconomy Blueprint (2012)</td>
</tr>
</tbody>
</table>

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Science and technology serve Food & Nutrition Security

- **Availability**
  - Production
    - Climate, Resources, Technology, Trade, ...

- **Access**
  - Income
    - Prices, Markets, Own supply, Transfers, Infrastructures, Trade, ...

- **Utilization**
  - Quality & Quantity
    - Health & sanitation, Public health, Care, ...

- **Stability**

- **Innovation through science and technology**

A problem, if interlinkages among the 4 components are neglected

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Bioeconomy: Cascading and feed-backs driven by science, technology, innovation

- Resources
  - Biomass
  - Water
  - Land
  - Biodiversity

- Products
  - Food
  - Feed
  - Fiber
  - Energy

- Processing
  - Improved food industries
  - New chemical industries
  - Bio-refineries

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Innovation feeds the world – even more critical in bioeconomy context

Sources of productivity growth in world agriculture

Contribution to productivity

- Innovation
- Inputs
- Irrigation
- Area expansion

Rate of output growth (% per year)

- 1961–2009
- 1960s
- 1970s
- 1980s
- 1990s
- 2000s


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Ingredients of science policy for innovation in the bioeconomy

- Land use and soils
- Water management and quality
- Biodiversity (terrestrial / marine)
- Genetic resources (terrestrial / marine)
- Biotechnology (plant, animal)
- Livestock (terrestrial / marine)
- Nutrition and health
- Bio-mass (terrestrial / marine)
- Economics (linked value chains)
- Industrial (white) biotechnology
- Bio-refineries
- Recycling and energy conversion
Challenges of Bioeconomy for Agricultural Economics Profession

1. Noting the limitations of isolated value chain, agr. sector, and commodity analyses; learning about a much broader set of relevant technologies and intermediate and final demands related to “agriculture“

2. Addressing distributional effects related to the whole “agro-biomass” system in value webs with many externalities

3. Study of resource use conflicts (land, water), and tradeoffs in a much broader context

4. Expanding our methods for tackling the challenges:
   – Opportunities in industrial organization research, and mobilizing the whole ag. econ. tool box
   – Working with other disciplines (nutrition, ecology, biotech, biochem., etc.)

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Because bioeconomy is complex: Re-design of the international agriculture, food and nutrition science system!

- The challenges of agricultural development and food and nutrition security require a strong mechanism for science based assessment as a permanent institutional arrangement for the coming decades.
- A global body tasked with this could be mapped along the lines of the Intergovernmental Panel on Climate Change (IPCC), but avoiding its pitfalls from the outset.

An independent global research platform that facilitates the peer reviewed assessments on agriculture, food and nutrition is needed for delivering evidence based analyses for policy action with foresight.

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