Livestock Productivity and the Global Performance Gap

Carlos E. Ludena

Plenary session: Findings on livestock productivity gaps and trends, and their implications for natural resource use efficiency

Global Agenda of Action in Support of Sustainable Livestock Development

2-4 April 2012  FAO HQ  Rome, Italy
Outline of Presentation

• Productivity gap. Is there one?
• Looking at species and countries
• What data tells us: PFP vs TFP
• Methodology – Malmquist Index
• Input/output allocation
• Productivity Growth
• Technical change and efficiency
• Convergence in Livestock Productivity
The global performance gap

• Where are the largest gaps
  – Animal species and commodity
  – Production systems (grazing, mixed, industrial)
  – Countries/regions

• In this presentation, evidence for:
  – Animal species
  – Countries and regions
Productivity Gap: is there any evidence?

• Evidence regardless of use of productivity measurement
  – Partial Factor Productivity (PFP)
  – Total Factor Productivity (TFP)

• However, TFP offers a more complete picture of resource use (although limited to present discussion)
  – Land, water, nutrients, fossil energy, air
  – Gas emissions
PFP and TFP Measures

• PFP (yield) is the one mostly used
• TFP estimation very recent:
  – Problem in estimation: Input/output allocation
  – Product specific Malmquist Index (Nin-Pratt et al., 2003)): Crops and Livestock
  – Ludena et al. 2007: Crops, Ruminants (beef, dairy, sheep, and goats) and Non-Ruminants (pigs and poultry)
Difference between ruminants and non-ruminants

• PFP Evidence:
  – Difference between ruminants (beef, dairy, sheep, goats, horses), and non-ruminants (pigs, poultry)
  – Delgado et al. (1999): Between 1982-1994 average growth per year for beef grew was 0.5%, milk 0.2%, pork 0.6%, and poultry 0.7%
  – Rae and Hertel (2000) show that in Asia the rate of growth for non-ruminants is higher than ruminants
TFP vs PFP: Case of China

Ruminants

Non-Ruminants

PFP > TFP = farmers in China have substituted other inputs for animal stock. Improved feed efficiency and reduced labor usage.
TFP Productivity Measurement - Methodology

- Product-specific directional Malmquist index (Nin-Pratt et al., 2003)

\[
DM(t, t+1) = \left[ \begin{array}{c}
\left( + \tilde{D}_0^t \left( t, y_i^t, y_{-i}^t; y_i^t, 0 \right) + \tilde{D}_0^t \left( t+1, y_i^{t+1}, y_{-i}^{t+1}; y_i^{t+1}, 0 \right) \right) \\
\left( + \tilde{D}_0^{t+1} \left( t, y_i^t, y_{-i}^t; y_i^t, 0 \right) + \tilde{D}_0^{t+1} \left( t+1, y_i^{t+1}, y_{-i}^{t+1}; y_i^{t+1}, 0 \right) \right)
\end{array} \right]^{0.5}
\]
TFP Productivity Measurement - Methodology

• Malmquist index efficiency and technical change components:

\[
DEFF(t, t+1) = \frac{\left( + \tilde{D}_0^t \left( x^t, y^t, y^-_t ; y^t_i, 0 \right) \right)}{\left( + \tilde{D}_0^t \left( x^{t+1}, y^{t+1}, y^{t+1}_- ; y^{t+1}_i, 0 \right) \right)}
\]

\[
DTECH(t, t+1) = \left[ \frac{\left( + \tilde{D}_0^{t+1} \left( x^t, y^t, y^-_t ; y^t_i, 0 \right) \right)}{\left( + \tilde{D}_0^{t+1} \left( x^{t+1}, y^{t+1}, y^{t+1}_- ; y^{t+1}_i, 0 \right) \right)} \right]^{0.5}
\]
Technological and Efficiency Changes Compared

- Technological Change
- Efficiency Change or Catching-up

Diagram showing the relationship between points $A_t$, $B_t$, $A_{t+1}$, and $B_{t+1}$, with axes $y_1$ and $y_2$. The paths $S^t$ and $S^{t+1}$ indicate changes over time.
TFP Productivity Measurement - Data

• FAOSTAT: 116 countries, 1961-2001
• Output – Crops and Livestock (Ruminants and Non-Ruminants)
• Inputs
  – Land (Pasture, Arable and Permanent Crops)
  – Machinery (tractors, milking machines)
  – Animal stock
  – Feed
  – Fertilizers
  – Labor
## Input-Output Allocation

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable land and permanent crops</td>
<td>Crops</td>
</tr>
<tr>
<td>Land in pasture</td>
<td>Ruminants</td>
</tr>
<tr>
<td>Tractors and harvesters</td>
<td>Crops</td>
</tr>
<tr>
<td>Milking Machines</td>
<td>Ruminants</td>
</tr>
<tr>
<td>Ruminant Stock</td>
<td>Ruminants</td>
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<tr>
<td>Non-Ruminant Stock</td>
<td>Non-ruminants</td>
</tr>
<tr>
<td>Feed</td>
<td>Livestock</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>Crops</td>
</tr>
<tr>
<td>Labor</td>
<td>All</td>
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</table>
### Annual TFP Growth Rates (%) (1961-2001)

<table>
<thead>
<tr>
<th>Country/Region</th>
<th>Ruminants</th>
<th></th>
<th></th>
<th>Non-Ruminants</th>
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<tr>
<td></td>
<td>TFP</td>
<td>EFF</td>
<td>TCH</td>
<td>TFP</td>
<td>EFF</td>
<td>TCH</td>
</tr>
<tr>
<td>World</td>
<td>0.62</td>
<td>-0.03</td>
<td>0.65</td>
<td>2.10</td>
<td>-1.08</td>
<td>3.23</td>
</tr>
<tr>
<td>Developed Countries</td>
<td>0.93</td>
<td>-0.27</td>
<td>1.20</td>
<td>2.11</td>
<td>-1.36</td>
<td>3.52</td>
</tr>
<tr>
<td>Developing Countries</td>
<td>0.38</td>
<td>-0.27</td>
<td>0.65</td>
<td>2.38</td>
<td>-0.90</td>
<td>3.31</td>
</tr>
<tr>
<td>Economies in Transition</td>
<td>0.76</td>
<td>-0.50</td>
<td>1.27</td>
<td>3.24</td>
<td>-1.84</td>
<td>5.17</td>
</tr>
<tr>
<td>East and South East Asia</td>
<td>-0.27</td>
<td>-1.14</td>
<td>0.87</td>
<td>1.65</td>
<td>-1.91</td>
<td>3.56</td>
</tr>
<tr>
<td>China</td>
<td>2.87</td>
<td>1.88</td>
<td>0.97</td>
<td>3.39</td>
<td>-1.90</td>
<td>5.39</td>
</tr>
<tr>
<td>Middle East/North Africa</td>
<td>-0.03</td>
<td>-1.28</td>
<td>1.25</td>
<td>1.54</td>
<td>-0.53</td>
<td>2.07</td>
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<td>Sub-Saharan Africa</td>
<td>0.59</td>
<td>-0.05</td>
<td>0.64</td>
<td>0.80</td>
<td>-0.40</td>
<td>1.21</td>
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<td>Latin America and Carib.</td>
<td>0.12</td>
<td>-1.01</td>
<td>1.13</td>
<td>2.64</td>
<td>-1.12</td>
<td>3.76</td>
</tr>
<tr>
<td>Brazil</td>
<td>1.20</td>
<td>-0.31</td>
<td>1.51</td>
<td>4.33</td>
<td>0.55</td>
<td>3.76</td>
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</tbody>
</table>
Taking a closer look to meat, dairy, poultry and pig production

<table>
<thead>
<tr>
<th>Region</th>
<th>Ruminants</th>
<th></th>
<th>Non-Ruminants</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Meat</td>
<td>Dairy</td>
<td>Poultry</td>
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<tr>
<td>Ruminants</td>
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<tr>
<td>Developed</td>
<td>6.16</td>
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<td>Developing</td>
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<td>1.60</td>
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<tr>
<td>Non-Ruminants</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Developed</td>
<td>4.98</td>
<td></td>
<td>10.88</td>
<td>3.20</td>
</tr>
<tr>
<td>Developing</td>
<td>1.72</td>
<td></td>
<td>2.93</td>
<td>3.33</td>
</tr>
<tr>
<td>Ruminants &amp; Non-Ruminants</td>
<td></td>
<td>5.45</td>
<td>5.51</td>
<td>10.66</td>
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<tr>
<td>Developed</td>
<td>1.05</td>
<td>1.71</td>
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<td>3.28</td>
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## World Productivity Growth by decade (annual TFP growth rates, %)

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<thead>
<tr>
<th>Period</th>
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<th>Non-Ruminants</th>
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<td></td>
<td>TFP</td>
<td>EFF</td>
<td>TCH</td>
<td>TFP</td>
</tr>
<tr>
<td>1961-00</td>
<td>0.62</td>
<td>-0.03</td>
<td>0.65</td>
<td>2.10</td>
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<tr>
<td>1961-70</td>
<td>0.00</td>
<td>-0.88</td>
<td>0.89</td>
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<tr>
<td>1971-80</td>
<td>0.31</td>
<td>-0.39</td>
<td>0.70</td>
<td>0.72</td>
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<tr>
<td>1981-90</td>
<td>1.13</td>
<td>0.70</td>
<td>0.43</td>
<td>2.71</td>
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<tr>
<td>1991-00</td>
<td>1.06</td>
<td>0.50</td>
<td>0.57</td>
<td>2.72</td>
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</table>
# Productivity Growth by Decade (annual TFP growth rates, %)

<table>
<thead>
<tr>
<th>Period</th>
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<td></td>
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<td>EFF</td>
<td>TFP</td>
<td>TCH</td>
<td>EFF</td>
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<tr>
<td><strong>Ruminants</strong></td>
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<td></td>
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</tr>
<tr>
<td>1961-2001</td>
<td>0.93</td>
<td>1.20</td>
<td>-0.27</td>
<td>0.38</td>
<td>-0.27</td>
<td>0.65</td>
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<tr>
<td>1961-1971</td>
<td>0.84</td>
<td>0.94</td>
<td>-0.10</td>
<td>-0.61</td>
<td>0.85</td>
<td>-1.46</td>
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<tr>
<td>1971-1981</td>
<td>0.73</td>
<td>0.73</td>
<td>0.00</td>
<td>0.17</td>
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<tr>
<td>1981-1991</td>
<td>1.37</td>
<td>1.37</td>
<td>0.00</td>
<td>0.70</td>
<td>0.70</td>
<td>0.00</td>
</tr>
<tr>
<td>1991-2001</td>
<td>0.79</td>
<td>0.79</td>
<td>0.00</td>
<td>1.28</td>
<td>3.02</td>
<td>-1.80</td>
</tr>
<tr>
<td><strong>Non-Ruminants</strong></td>
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<td>3.31</td>
<td>-0.90</td>
</tr>
<tr>
<td>1961-1971</td>
<td>1.98</td>
<td>1.95</td>
<td>0.03</td>
<td>2.39</td>
<td>1.35</td>
<td>1.04</td>
</tr>
<tr>
<td>1971-1981</td>
<td>1.83</td>
<td>1.83</td>
<td>0.00</td>
<td>1.08</td>
<td>1.08</td>
<td>0.00</td>
</tr>
<tr>
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<td>1.57</td>
<td>0.00</td>
<td>3.38</td>
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<td>0.00</td>
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<tr>
<td>1991-2001</td>
<td>3.07</td>
<td>4.87</td>
<td>-1.80</td>
<td>2.68</td>
<td>3.99</td>
<td>-1.31</td>
</tr>
</tbody>
</table>
Productivity Growth Convergence

• Is there a common trend for livestock (ruminant and non-ruminant) factor productivities across countries?

• Use of efficiency time series (Bernard and Durlauf; Johansen, 1988; Cornwell and Watcher, 1999)

• Test for unit roots (non-stationary series) and then cointegration (Johansen, 1991)
  – Linear combination of non-stationary series is stationary => series move together in the long run.
Convergence in Non Ruminants

- Ruminants
  - Divergence between developed and developing countries (DC’s)

- Non-Ruminants
  - Evidence of catching-up
  - Convergence of EIT and Latin America to developed countries
  - Convergence of Sub-Saharan Africa to Europe, Asia and Latin America
Conclusions

• **Productivity growth in livestock**
  – Different productivity growth rates among species
  – Non-Ruminants > Ruminants
  – Poultry seems to have highest growth rate in developed countries
  – Beef vs Milk → inconclusive

• **Developing vs Developed**
  – Developed – Ruminants
  – Developing – Non-Ruminants

• **Convergence**
  – Catching-up in non-ruminants
QUESTIONS

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Cumulated Productivity Growth in Brazil (%), 1961-2000

TFP Agriculture
TFP Crops
TFP Ruminants
TFP Non-Ruminants

REFORMS
Cumulated Productivity Growth in Cuba (%), 1961-2000

- TFP Agriculture
- TFP Crops
- TFP Ruminants
- TFP Non-Ruminants

Soviet Union Collapse

Reforms
Policy reforms and cumulative productivity growth in China

TFP Agriculture
TFP Crops
TFP Ruminants
TFP Non-Ruminants

Policy reforms and cumulative productivity growth in China

REFORMS
Efficiency in $y_1$’s direction of a production point in $t + 1$ with technology in $t$ as reference.
Distance Functions and Productivity Indices

\[
D_0^t \left( \chi^t, y^t \right) \equiv \frac{OA_t}{OB_t}
\]

\[
D_0^t \left( \chi^{t+1}, y^{t+1} \right) \equiv \frac{OA_{t+1}}{OB_t}
\]

\[
D_0^{t+1} \left( \chi^t, y^t \right) \equiv \frac{OA_t}{OB_{t+1}}
\]

\[
D_0^{t+1} \left( \chi^{t+1}, y^{t+1} \right) \equiv \frac{OA_{t+1}}{OB_{t+1}}
\]
Distance to the frontier measured in different directions
Limitations of the study

• Directional Malmquist Index
  – Not always defined
  – Possible reallocation factor bias in the measure - movement of unallocated inputs

• Data – zero output in pork production for some countries

• Input/Output Aggregation and dissaggregation
  – i.e. feed in livestock

• Regional Aggregation and dissaggregation