LAND SUPPLY ELASTICITIES

Overview of available estimates and recommended values for MAGNET

Andrzej Tabeau
John Helming
George Philippidis

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Andrzej Tabeau and John Helming are from Wageningen Economic Research (WEcR), Wageningen University. George Philippidis is currently with the Aragonese Agency for Research and Development (ARAID) and WEcR. The outcome is coming from work done within the JRC, since the author was at that time affiliated with the JRC.
1. Introduction

The land supply elasticity with respect to the land price (land rent) is a key parameter in determining the land supply impacts of economic shocks and policies and the resulting impacts on food prices and food and nutrition security. For example, Elbeid at al., 2011 shows that halving the area expansion elasticities leads to 15% lower land expansion in Brazil necessary for 25% increase in ethanol consumption. However, values for land supply elasticities are rarely available in the literature. Due to lack of reliable time series data on land prices and concerns about the quality of Utilised Agricultural Area data, they are only available estimated for some countries of the world.

In this overview we calculate land supply elasticities for several world regions and countries adapting method proposed in the literature and showing available published estimates.

A comparison between current and new values of MAGNET land elasticities can be found in Appendix C. Appendix D gives a quick operating instruction on how to run MAGNET using the new land set of land supply elasticities in MAGNET.

2. Estimates of land supply elasticities available in the literature

A review of the literature yields econometric estimates of land supply elasticities in respect of land prices only for selected EU countries as shown in Table 1 (Cixous, 2006; Boitier, 2011; Sensor 2006). The estimated elasticities values vary significantly depending on county and source. For instance for Finland the following three values has been found: 4.65, 0.08 and 0.61.

<table>
<thead>
<tr>
<th></th>
<th>AT</th>
<th>BE</th>
<th>DE</th>
<th>DK</th>
<th>ES</th>
<th>FI</th>
<th>FR</th>
<th>GR</th>
<th>IE</th>
<th>IT</th>
<th>LU</th>
<th>NL</th>
<th>PT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boitier, 2011</td>
<td>1.19</td>
<td>0.23</td>
<td>1.09</td>
<td>0.23</td>
<td>0.36</td>
<td>4.65</td>
<td>1.42</td>
<td>0.36</td>
<td>0.07</td>
<td>0.32</td>
<td>1.29</td>
<td>0.12</td>
<td>0.30</td>
</tr>
<tr>
<td>Cixous, 2006</td>
<td>-</td>
<td>0.07</td>
<td>0.14</td>
<td>0.11</td>
<td>0.16</td>
<td>0.08</td>
<td>0.17</td>
<td>0.11</td>
<td>-</td>
<td>0.15</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sensor, 2006</td>
<td>0.14</td>
<td>0.15</td>
<td>0.16</td>
<td>0.06</td>
<td>0.10</td>
<td>0.61</td>
<td>0.13</td>
<td>0.17</td>
<td>0.04</td>
<td>0.10</td>
<td>-</td>
<td>0.08</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Table 1 - Econometrically estimated land prices elasticities for selected EU countries
Gurgel at al., 2007 calculates land supply elasticities by dividing the percentage change in agricultural area by percentage change in land price. He calculated the elasticities using 1990–2005 data assuming US percentage price change for all regions. Baldos and Hertel, 2013 extended this approach for additional countries and calculated 5-year elasticities. These are equal to about one third of Gurgel elasticities. The ratio was set base on US elasticities estimated for 5- and 15-years periods by Ahmed at al. 2008. The calculated elasticities are in Table 2.

Several authors estimate land supply elasticities in respect of crop prices or crop returns instead of land prices. However, assuming that crop prices or returns are capitalized in land prices, we can use these elasticities to derive elasticities in respect of land prices. Salhofer (2000) provides the following formula linking land supply elasticity $E_l$ in respect of land price (rental rate of land) with land supply elasticity $E_c$ in respect of the output price of related agricultural commodity:

$$E_l = \frac{a}{b} \cdot E_c$$  \hspace{1cm} (1)

where a is the cost share of land for the agricultural commodity under consideration and b is the fraction of benefits from an increase in the price of commodity that accrue as benefits to landowners. In the long run, b is close to 1 but in medium term Salhofer (2000) proposes values between 1/3 and 2/3.

### Table 2 - Calibrated land prices elasticities for different countries and world regions for different periods

<table>
<thead>
<tr>
<th>Gurgel at al., 2007</th>
<th>Baldos and Hertel, 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>0.12</td>
</tr>
<tr>
<td>Canada</td>
<td>0.12</td>
</tr>
<tr>
<td>Japan</td>
<td>0.12</td>
</tr>
<tr>
<td>Australia, New Zealand</td>
<td>0.12</td>
</tr>
<tr>
<td>EU</td>
<td>0.12</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>0.12</td>
</tr>
<tr>
<td>Former Soviet Union</td>
<td>0.12</td>
</tr>
<tr>
<td>High Income East Asia</td>
<td>0.38</td>
</tr>
<tr>
<td>China</td>
<td>0.15</td>
</tr>
<tr>
<td>India</td>
<td>0.31</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0.60</td>
</tr>
<tr>
<td>Africa</td>
<td>0.60</td>
</tr>
<tr>
<td>Middle East</td>
<td>0.32</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.60</td>
</tr>
<tr>
<td>Central and South America</td>
<td>0.60</td>
</tr>
<tr>
<td>Rest of the World</td>
<td>0.42</td>
</tr>
<tr>
<td>North America</td>
<td>0.04</td>
</tr>
<tr>
<td>Europe &amp; Central Asia</td>
<td>0.04</td>
</tr>
<tr>
<td>East Asia &amp; Pacific</td>
<td>0.04</td>
</tr>
<tr>
<td>South Asia</td>
<td>0.10</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>0.20</td>
</tr>
<tr>
<td>Middle East &amp; North Africa</td>
<td>0.11</td>
</tr>
<tr>
<td>Latin America &amp; Caribbean</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Land supply elasticities in respect of crop prices of returns available in the literature are presented in Table 3. Barr at al., 2001 employed similar formula as proposed by Gurgel at al., 2007 but used expected returns from land instead of land price. Other authors used econometric methods to estimate elasticities.

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1 Gurgel at al., 2007 expects globally the similar price movements of land around the world because of global commodity trade. Also, he refers to evidence provided by Sutton and Web, 1988.
Table 3 - Prices elasticities with respect to crop prices or returns and derived elasticities with respect of land prices

<table>
<thead>
<tr>
<th>Country</th>
<th>Price elasticity for cropland area wrt:</th>
<th>Price elasticity for total agricultural area wrt:</th>
<th>Source for elasticities wrt. crop prices and returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>0.3</td>
<td>0.005-0.028</td>
<td>Scott (2013)</td>
</tr>
<tr>
<td></td>
<td>0.26-0.33</td>
<td></td>
<td>Roberts &amp; Schlenker (2011; 2013)†</td>
</tr>
<tr>
<td></td>
<td>0.007-0.029</td>
<td></td>
<td>Barr et al. (2011)</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.22-0.40</td>
<td>0.019-0.44</td>
<td>Roberts &amp; Schlenker (2011; 2013)†</td>
</tr>
<tr>
<td></td>
<td>0.38-0.90</td>
<td></td>
<td>Barr et al. (2011)</td>
</tr>
<tr>
<td></td>
<td>0.19-0.44</td>
<td>0.007-0.245</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.030-0.122</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.013-0.052</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.003-0.008</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>0.030-0.070</td>
<td></td>
<td>Roberts &amp; Schlenker (2013)†</td>
</tr>
<tr>
<td>India</td>
<td>0.006-0.015</td>
<td></td>
<td>Roberts &amp; Schlenker (2013)†</td>
</tr>
<tr>
<td>Thailand</td>
<td>0.100-0.250</td>
<td>0.018-0.044</td>
<td>Roberts &amp; Schlenker (2013)†</td>
</tr>
</tbody>
</table>

† Only selected crops included (total of corn, wheat, rice and soybeans).
‡ Own calculations form formula (1) using: (a) crop price elasticities (columns 2 to 5). (b) cost share of land for crops from GTAP 9 database (Badri at al. 2015) (c) assumed fraction 0.5 of benefits from an increase in the price of commodity that accrue as benefits to landowners and (d) assumed ratio of 3.5 of cropland area elasticities to total agricultural area elasticities in the long run (Barr et al., 2011 results for Brazil).

3. MAGNET estimates of land supply elasticities

**Elasticities based on the original MAGNET land supply function**

The original MAGNET land supply functional form makes it possible to derive land supply elasticities in the easy way. The assumed function is:

\[ L = A - B/P \]  

(2)

where L is land supply, P is the real land price, A is the maximum available agricultural land area (the land asymptote), and B is a positive parameter. The resulting land supply elasticity E in respect of land price is defined as:

\[ E = \frac{A}{L} - 1 \]  

(3)

We used data provided by IMAGE model (Stehfest, at al., 2014) for almost all world countries to calculate these elasticities. Elasticities for IMAGE model regions and major countries are presented in Table 4. According to this formula, specific land supply elasticity depends upon the ratio of the asymptote to land used for agriculture, and therefore it crucially depends on estimates of maximum available agricultural land area, A, which are subject of many uncertainties (Mandryk et al. 2015). The elasticity can differ, depending on estimates of land availability estimates, and often results in high land supply elasticities which are inconsistent with observed of agricultural area changes.
Elasticities calculated from agricultural land and return time series

We also calculated land supply elasticities adapting method used by Gurgel at al. (2007) and Barr et al. (2011) for several world regions and countries. We calculated land supply elasticities directly from the observed percentage changes in agricultural land and percentage changes in total return of agriculture per unit of agricultural land. In this approach, we assume that returns from agricultural production are capitalized in land prices in the long run and therefore percentage changes in return of agriculture per unit of agricultural land are good proxies for unobserved percentage changes in land prices.

We use two alternative data sources to calculate these elasticities:
- CAPRI database
- FAO and World bank data

**CAPRI database**

The CAPRI database (Britz and Witzke, 2014) includes time series of land balances, prices of agricultural products, yields per hectare and gross margins per hectare (both excluding and including agricultural subsidies) for agricultural activities in the EU Member States, Norway, Western Balkan countries and Turkey (list of countries is presented in Appendix A). To convert to real prices, the historical development of the consumer price index is used.

As explained above, we estimate the land supply elasticities directly from the observed changes in Utilised Agricultural Area (UAA) and changes in average gross margins, including subsidies (all measured in real prices) per unit of agricultural land. We calculate land supply elasticities over different time periods. This is mainly steered by the introduction of hectare premiums in 1993 in the EU15, and farm payments and single area payments in 2003/2004 in EU15 and EU12 respectively. The percentage change in utilised agricultural area is corrected for the observed long term trend in the supply of utilised agricultural area. Appendix A gives the list of agricultural activities included in the calculation of available agricultural land and the average gross margin, including agricultural subsidies per ha per period per country. Average agricultural land and gross margin are calculated for the periods 2000 to 2003 and 2006 to 2010².

It is important to note that:

A. positive land supply elasticities are especially due to decreasing agricultural area and decreasing gross margins;
B. if land supply elasticity becomes negative, its value is put equal to 0.015.

² Some countries are treated a little differently. Land supply elasticity in Germany includes fallow land as agricultural land. This is due to uncertainties concerning fallow land in Germany in the database. For Turkey a different period is used namely from 2004 to 2006 and from 2008 to 2010.
**FAO and World bank data**

Total agricultural area (in 1000 ha) and agricultural value added (in constant 2005 US$) was used to calculate elasticities using data from the FAO\(^3\) and World Bank World Development Indicators (WDI) database\(^4\). Agricultural value added was divided by agricultural area to compute value added per hectare to use as a proxy for total agricultural returns.

The land supply elasticities for individual countries are calculated directly from the data using periods that can be different per individual country depending on the data quality. Another reason to use different periods is that we expect a positive elasticity so land and value added per hectare needs to move in the same direction in the chosen period. For all countries for which data do not show an increase of agricultural area since 2000 and at the same time show increase of agricultural return (e.g. USA, South Korea, Japan, Oceania, Australia and India), we choose elasticity 0.015. This elasticity is close to zero but at the same time does not make the land supply function too vertical which could create problems when solving a model.

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\(^3\) [http://faostat.fao.org/](http://faostat.fao.org/)

Table 4, we present calculated land supply elasticities for IMAGE and major countries. Individual country results are presented in the next section. For Europe, agricultural land and value added moves in different directions according FAO and World Bank data. The agricultural land is decreasing and at the same time agricultural value added is increasing. This makes it impossible to calculate positive elasticities. Therefore to obtain land supply elasticities for Europe, CAPRI data have been used.
Table 4 - Land supply elasticities for IMAGE model regions and major countries

<table>
<thead>
<tr>
<th>IMAGE regions</th>
<th>Elasticity from the formula A/L-1</th>
<th>Acreage elasticity wrt total value added agriculture (adapted “Gurgel” approach)</th>
<th>Source of adapted “Gurgel” elasticities</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>0.595</td>
<td>0.048</td>
<td>FAO/WB</td>
<td>No positive elasticity found</td>
</tr>
<tr>
<td>USA</td>
<td>0.232</td>
<td>0.015</td>
<td>FAO/WB</td>
<td>No positive elasticity found</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.228</td>
<td>0.103</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Rest of Central America</td>
<td>0.421</td>
<td>0.131</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>0.596</td>
<td>0.120</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Rest of Southern America</td>
<td>0.501</td>
<td>0.376</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Northern Africa</td>
<td>0.017</td>
<td>0.016</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Western Africa</td>
<td>0.263</td>
<td>0.096</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Eastern Africa</td>
<td>0.188</td>
<td>0.081</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Southern Africa</td>
<td>0.616</td>
<td>0.101</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>EU16</td>
<td>0.319</td>
<td>0.043</td>
<td>CAPRI</td>
<td></td>
</tr>
<tr>
<td>Rest of Western Europe</td>
<td>0.404</td>
<td>0.061</td>
<td>CAPRI</td>
<td></td>
</tr>
<tr>
<td>EU12</td>
<td>0.197</td>
<td>0.024</td>
<td>CAPRI</td>
<td></td>
</tr>
<tr>
<td>Rest of Eastern Europe</td>
<td>0.171</td>
<td>0.062</td>
<td>CAPRI</td>
<td></td>
</tr>
<tr>
<td>Turkey</td>
<td>0.319</td>
<td>0.090</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Ukraine Plus</td>
<td>0.155</td>
<td>0.034</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Asia-Stan Countries</td>
<td>0.008</td>
<td>0.034</td>
<td>FAO/WB</td>
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<td>Russia Plus</td>
<td>0.473</td>
<td>0.036</td>
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<td>0.048</td>
<td>0.015</td>
<td>FAO/WB</td>
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<td>India Plus</td>
<td>0.153</td>
<td>0.019</td>
<td>FAO/WB</td>
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<tr>
<td>Korea</td>
<td>0.000</td>
<td>0.015</td>
<td>No positive elasticity found</td>
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<td>China Plus</td>
<td>0.067</td>
<td>0.020</td>
<td>FAO/WB</td>
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<tr>
<td>South East Asia</td>
<td>1.201</td>
<td>0.401</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Indonesia Plus</td>
<td>1.357</td>
<td>0.620</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>0.000</td>
<td>0.015</td>
<td>No positive elasticity found</td>
<td></td>
</tr>
<tr>
<td>Oceania</td>
<td>0.161</td>
<td>0.015</td>
<td>No positive elasticity found</td>
<td></td>
</tr>
<tr>
<td><strong>Selected countries</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>0.126</td>
<td>NA</td>
<td></td>
<td>No positive elasticity found</td>
</tr>
<tr>
<td>China</td>
<td>0.079</td>
<td>0.021</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>0.183</td>
<td>NA</td>
<td></td>
<td>No positive elasticity found</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1.357</td>
<td>0.620</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Russia</td>
<td>0.485</td>
<td>0.037</td>
<td>FAO/WB</td>
<td></td>
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<tr>
<td>Ukraine</td>
<td>0.091</td>
<td>0.024</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Belarus</td>
<td>0.469</td>
<td>0.038</td>
<td>FAO/WB</td>
<td></td>
</tr>
<tr>
<td>Argentina</td>
<td>0.263</td>
<td>0.685</td>
<td>FAO/WB</td>
<td></td>
</tr>
</tbody>
</table>
4. Land supply elasticities selected for MAGNET

Because of relatively limited documentation and literature concerning land supply elasticities the choice of these elasticities for medium and long term projections is rather subjective matter. This can be illustrated by choice of elasticities used in MIRAGE model. MIRAGE, Updated Version of the Model for Trade Policy Analysis (Decreux and Valin, 2007), uses land supply elasticities 0.25 for land constrained countries and 1 for other countries. This model was, e.g., used by Bouët and Laborde, 2010 for evaluation of Doha trade liberalization proposals. In the MIRAGE-BIOF model used in the study “European Union and United States Biofuel Mandates, Impacts on World Markets (Al-Riffai P., Dimaranan B. and Laborde D., 2010), the land supply elasticity was set at 0.02 for EU and USA and at 0.035 for Brazil. In the similar study by the same authors (Al-Riffai P., Dimaranan B. and Laborde D., 2010A), the varying by region elasticities between 0.05 and 0.1 are used. Finally, in another study using MIRAGE-BIOF model (Laborde and Valin, 2012) elasticities between 0.01 and 0.05 are employed. As the authors of these papers point out, the land supply elasticity is uncertain parameter and they advise to conduct sensitivity analyses around its chosen value in the simulation experiment.

This overview of land supply elasticities available in literature suggests that land supply elasticities are rather low. This is confirmed by statistical data which shows that agricultural areas for majority of countries increase very slowly or even decrease since 2000; while agricultural value added per unit of agricultural area often increases significantly. Our choice of land supply elasticities for MAGNET is as follows:

We chose elasticities calculated from agricultural land and return time series (as described for previous section) for all countries for which data were available.

We choose elasticity 0.015 for countries that are analysed but for which data do not show an increase of agricultural area since 2000 and at the same time show increase of agricultural return (e.g. European countries, USA, South Korea, Japan, Oceania, Australia and India). This elasticity is close to zero but at the same time does not make the land supply function too vertical which could create problems when solving a model.

For selected countries for which the elasticities cannot be calculated because of lack of agricultural land and return time series the following approach was followed. First the ratio between ‘our’ land supply elasticity (see Appendix B) and the elasticity using formula (3) for neighbouring countries was calculated. Next, this ratio is multiplied with the selected country specific land supply elasticity using formula (3). Selected countries are especially located in Western and Southern Africa, and Rest of South America. These three IMAGE regions are characterised by relatively high land supply elasticity from the formula (A/L-1), while elasticities based on FAO and World Bank data elasticity was judged too low. The selected countries are Venezuela, El Salvador, Côte d’Ivoire, Gambia, Ghana, Liberia, Congo and Tanzania.

We choose elasticity 0.015 for all remaining, mostly small, countries. The land supply elasticities for all world countries are presented in the Appendix B.
5. References


Badri N.G., Aguiar A. and McDougall R. (eds.) (2015), Global Trade, Assistance, and Production: The GTAP 9 Data Base, Center for Global Trade Analysis, Purdue University.


Authors: Andrzej Tabeau and John Helming, LEI Wageningen UR.
## 6. Appendix A. Countries and agricultural activities in CAPRI used to calculated land supply elasticities

<table>
<thead>
<tr>
<th>Countries</th>
<th>Agricultural activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL</td>
<td>Belgium SWHE soft wheat</td>
</tr>
<tr>
<td>DK</td>
<td>Denmark DWHE durum wheat</td>
</tr>
<tr>
<td>DE</td>
<td>Germany RYEM rye</td>
</tr>
<tr>
<td>EL</td>
<td>Greece BARL barley</td>
</tr>
<tr>
<td>ES</td>
<td>Spain OATS oats</td>
</tr>
<tr>
<td>FR</td>
<td>France MAIZ grain maize</td>
</tr>
<tr>
<td>IR</td>
<td>Ireland OCER other cereals</td>
</tr>
<tr>
<td>IT</td>
<td>Italy RAPE rape</td>
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8. Appendix C. Old and new land supply elasticities in AgriFood2030

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9. Appendix D. New set of land supply elasticities in MAGNET

New land supply elasticities are introduced into new AgriFood2030 model version called MAGNET_3_09_AgriFood2030D committed on the svn sever. To introduce these elasticities into the model, \land\AggregateLandSupplyElasticity box should be checked in Database tab, Chose includes. Otherwise, program will not work.
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