Estimating the impact of fertilizer support policies: A CGE approach

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Abstract

Fertilizers represent a key input into crop production. Volatile energy prices and limits to mining resources have resulted in increased fertilizer costs for farmers, and several emerging economies have identified fertilizers as an important angle to improve agricultural production and incomes. However support fertilizer use and production comes at a cost to both welfare of a country due to subsidizing sectors and to the environment.

This article analyses support measures for fertilizers and shows how these policies may impact three key areas of concern namely welfare, environment and food security. The analysis is done with a computable general equilibrium model, MAGNET. Extending some earlier OECD analysis, for this paper MAGNET is extended to explicitly account for the three macronutrients: nitrogen (N), phosphorus (P2O5) and potassium (K2O).

Simulations show that fertilizer support policies reduce crop production costs and hence increase yields, production and incomes for crop farmers in subsidising countries. However fertilizer support policies also increase CO2 emissions worldwide and thus contribute to climate change. While fertilizer support policies promote food security, they do not necessarily increase welfare in the subsidizing countries.

Keywords: CGE modelling, fertilizers, policy support measures

Introduction

Fertilizers represent a key input into crop production. Emerging economies have identified fertilizers as an important angle to improve agricultural production and incomes. The intensity of fertilizer differs widely across countries (FAOSTAT, 2013). The five largest fertilizer users (China, India, USA, EU27, and Brazil) together account for 72% of the world's total fertilizer consumption. Especially in a range of developing countries of sub-Saharan Africa, fertilizer use is known to be still very low (Morris et al., 2007).

While the use of fertilizers undeniably improves agricultural production, fertilizers also bring potential concerns. Within the majority of OECD countries there is quite some environmental and consumer safety concerns. Intensification of fertilizer use is widely seen by society as an undesirable trend due to its perceived high environmental and consumer costs related to e.g. GHG emissions or increased nitrate content in food products. Policies related to fertilizers in OECD countries are therefore focused on the control of environmental and human health impacts of fertilizer manufacturing and use and are based on regulatory instruments, rather than on economic (support) instruments.

By contrast, support of fertilizer use remains central to agricultural growth strategies in non-OECD countries, although in some of these countries concerns about fertilizer misuse or overuse are already voiced. An increase in fertilizer use was one of the key factors of agricultural productivity improvements, supporting the Green Revolution in India and Indonesia, and agricultural growth in China and Brazil in more recent decades. Furthermore, development of domestic fertilizer manufacturing was part of these countries' industrial strategies. In Russia and Ukraine, "chemicalisation" was one of the principal policies to achieve growth targets in agriculture in the times of the Soviet Union. Governments in all these countries applied policies across the supply chain to support fertilizer consumption, which included considerable interventions in fertilizer manufacturing and distribution. Such broad-ranging systems continue to exist in China, India, and Indonesia, although they have lost much of their rigidity. As part of general market reforms, Brazil, Russia, and Ukraine have eliminated previous state regulation. However, these countries continue to support fertilizer use through direct subsidies to producers or through preferential lending. Most recently, the 2008 financial crisis prompted ad hoc interventions in fertilizer pricing in Russia and Ukraine.

This article seeks to improve the understanding of the impact various fertilizer policies have along the agricultural supply chain. Fertilizer support policies in general try to promote food security but may have adverse impacts on welfare and the environment. Building on an earlier OECD study (von Lampe et al. (2014), we therefore focus our results on three key areas of concern namely what impact fertilizer support policies have on welfare, CO2 emissions and food security. These impacts are analysed with the computable general equilibrium model MAGNET. Four countries specifically have significant fertilizer support policies: India, Indonesia, Russian Federation and China. In these four countries, public support is estimated to reduce fertilizer costs to farmers by between 5% and 68% below fertilizer production costs. We investigate an extreme case where all fertilizer support policies are removed worldwide.

MAGNET has first been used in von Lampe et al (2014) to analyse the impacts of fertilizer support policies. In contrast to that OECD study, for this paper MAGNET is extended to explicitly include the three macronutrients: nitrogen (N), phosphorus (P2O5) and potassium (K2O) in order to account for differences in production processes, policies and impacts. Within the group of fertilizers providing macro-nutrients to crops, a fundamental distinction should be made between nitrogen on the one hand, and phosphorus and potassium on the other. Both in terms of production costs as in terms of environmental impacts these three nutrients differ.

The production of nitric fertilizers is a highly energy intensive process, and production costs depend strongly on energy prices. Consequently, the production of nitrogen-based fertilizers — while undertaken in most countries — is generally cheaper in countries with large supplies of energy products and hence low energy prices. Policies often aim at reducing energy costs in the production of nitric fertilizers, with the objective to provide the fertilizer to domestic farmers at lower costs. In turn, phosphorus and potassium are essentially mined products, and while important processing is required for both minerals, transformation to the final fertilizers is more demanding – and hence more costly – for phosphate than for potassium. For these two fertilizer groups, transportation and handling represent important cost elements, and several countries provide subsidies to reduce costs related to these activities.

Another key distinction between nitrogen on the one hand and potassium and phosphorus on the other is the environmental impact. Nitrogen use causes apart from local pollution to ground water also CO2 emissions while potassium and phosphorus only cause local pollution but do not contribute to climate change. Therefore the environmental impact of the three nutrients is quite different.

The remaining of this paper is organised as follows: Section 2 of this article describes the methodology of the MAGNET model and the adjustments to include fertilizer nutrients. The scenarios analysed are presented in section 3. The results of the main scenarios are presented in section 4. Section 5 gives some conclusions.

Methodology

The **M**odular **A**pplied **G**e**N**eral **E**quilibrium **T**ool (MAGNET) is a recursive dynamic, multi-regional, multi-commodity CGE model, covering the entire global economy (Woltjer and Kuiper, 2012). As with other CGE models, MAGNET explicitly represents the economic linkages across the sectors of each regional economy. This is particularly important when analysing policy effects in sectors that are vertically linked with each other, such as fertilizers, agriculture and biofuels. It is built upon the GTAP model (Hertel, 1997) and is the successor of the LEITAP model which has been widely used for policy analysis (Banse et al., 2008; van Meijl et al., 2006; Nowicki et al., 2009, Woltjer, 2011). The MAGNET model is modular in nature and extends the GTAP model through the addition of a number of policy-relevant modules. MAGNET includes the following modular extensions to improve the representation of the agricultural, biofuel and fertilizer sectors and related policies:

- **Dynamic segmented factor markets**: Factor markets are divided into agricultural and non-agricultural labour and capital. In doing so, MAGNET accounts for differences in wages and returns to assets between the agricultural and the non-agricultural sector. The module also contains a dynamic component that takes into account the fact that the differences are larger in the short term than in the long term.

- **Land supply**: MAGNET implements a land supply curve which specifies the relationship between land supply and land price. As demand increases, more land will be used for agricultural production leading to land scarcity and therefore increased land prices. Total land supply is exogenous in the standard GTAP model. In this extended version, total agricultural land supply is modelled using a land supply curve specifying the relationship between land supply and a land rental rate in each region (van Meijl et al., 2006, Eickhout et al., 2009). Land supply to agriculture can be adjusted by idling agricultural land, converting non-agricultural land to agriculture, converting agricultural land to urban use, and agricultural land abandonment.

  Figure 1gives the general idea behind the land supply curve. When agricultural land use approaches potential land use ($\overline{L}$), farmers are forced to use less productive land with higher production costs (strongly increasing part of the supply curve). As a consequence, in land-abundant regions like South America and for members of NAFTA, an increase in demand from D_1 to D_1^* (left-hand side of Figure A.1) results in a large increase in land use (from l_1 to l_2) and a modest increase in rental rates (from r_1 to r_2), while land scarce regions like India, Japan, Korea and Europe experience a small increase in land use and a large increase in the rental rate (right-hand side of Figure A.1; shift from D_2 to D_2^*).

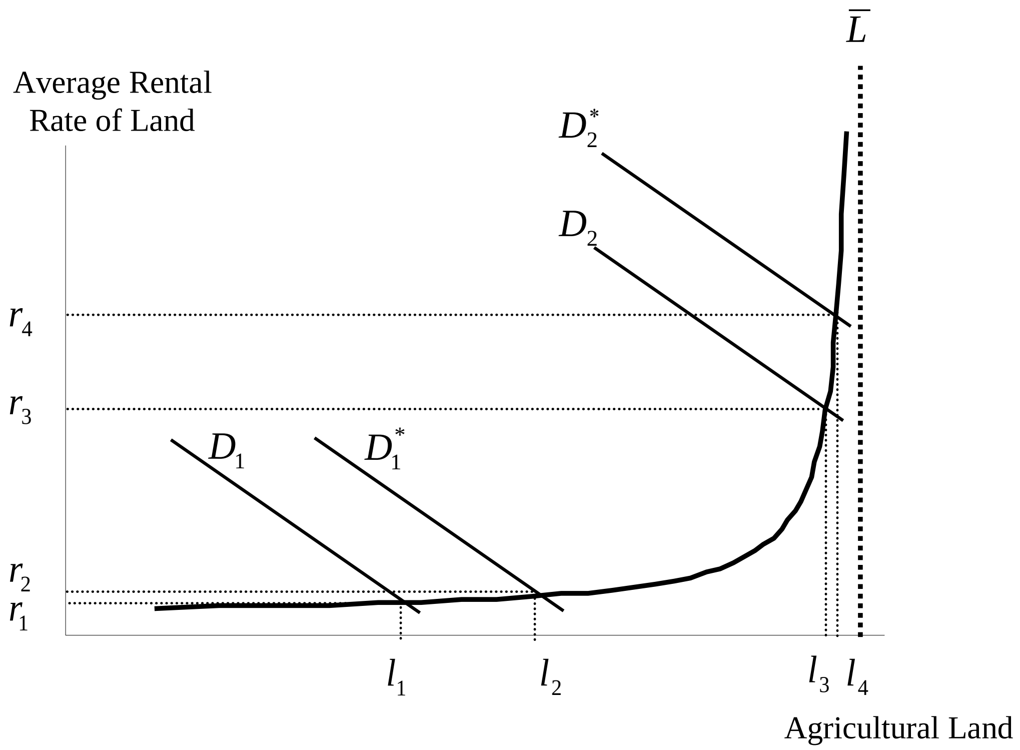

Figure 1 Impact of increased land demand for biofuel crops on land markets

- **Land allocation**: MAGNET assumes different substitutability amongst groups of land use types, with the degree of substitutability varying across but not within the groups and considers three hierarchical land use type groups (nests). Land heterogeneity is introduced by using a Constant Elasticity of Transformation (CET) function. To analyse the impact of fertilizers, the functioning of the land market is particularly crucial. We use an alternative to traditional methods by introducing a new demand structure that reflects the different degrees of substitutability between agricultural land uses according to the crops considered (Huang et al., 2004). The standard version of GTAP represents land allocation in a CET structure (Figure A.2) assuming that the various types of land use are imperfectly substitutable, but with equal substitutability among all land use types. For our purposes, the land use allocation structure is extended by taking into account that the degree of substitutability differs between types of land (Huang et al., 2004) using the more detailed OECD's Policy Evaluation Model (PEM) structure (OECD, 2003) (Figure 2). It distinguishes different types of land in a nested 3-level CET structure. The model covers several types of land use with different suitability levels for various crops (i.e. cereal grains, oilseeds, sugar cane/sugar beet and other agricultural uses).

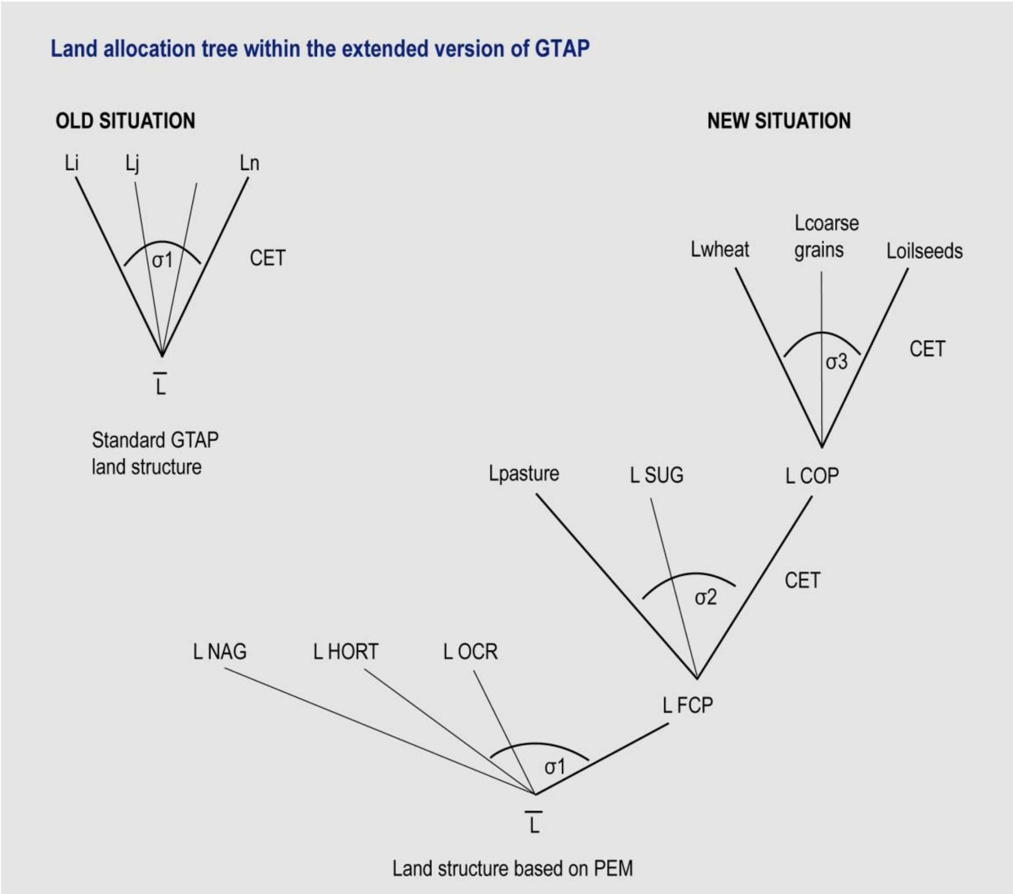

Figure 2 Land allocation tree within the extended version of GTAP

Following the PEM approach (OECD, 2003), there is nested substitutability between land for horticulture (LHORT), other crops (LOCR) and field crops and pasture (LFCP), between land for pasture (Lpasture), sugar crops (LSUG) and cereal, oilseed and protein crops (LCOP), and between land for wheat (Lwheat), coarse grains (Lcorse grains) and oilseeds (Loilseed).

The lower nest assumes a constant elasticity of transformation between 'vegetables, fruit and nuts' (HORT), 'other crops' (e.g. rice, plant-based fibers; OCR) and the group of 'Field Crops and Pastures' (FCP). The transformation is governed by the elasticity of transformation σ1. The FCP-group is itself a CET aggregate of Cattle and Raw Milk (both Pasture), 'Sugarcane and Beet' (SUG), and the group of 'Cereal, Oilseed and Protein crops' (COP). Here, the elasticity of transformation is σ2. Finally, the transformation of land within the upper nest, the COP-group, is modeled with an elasticity σ3. In this way the degree of substitutability of types of land can be varied between the nests. Agronomic features are captured to some extent. In general it is assumed that σ3> σ2 >σ1, which implies that it is easier to change the allocation of land within the COP group, while it is more difficult to move land out of COP production into, say, vegetables. The values of the elasticities are taken from PEM (OECD, 2003).

- **Livestock**: Livestock sectors are linked in various ways to the crop sectors. First, livestock sectors use crops in their feed mix to raise the animals. In the feed mix agricultural crops compete with processed feed and by-products from biofuel production (DDGS, oilcakes – see below). Secondly, crop and livestock sectors both compete in the land, labour and capital factor markets. Pasture land can be converted to crop land and vice versa.
- **A flexible constant elasticity of substitution (CES) tree production structure**: In this study, we use a two-level nested structure to represent substitution possibilities between pasture land and compound feed for animal production (first level) and substitution between compound feed feedstocks (second level). For crops we have two-level nested structure to represent substitution possibilities between crop land and fertilizers (first level) and substitution between various fertilizers (second level). Furthermore, we use a one-level nested CES structure to account for substitution among ethanol feedstocks. The blending sector and the fertilizer composite are explained in more detail below.
- **Consumption**: A dynamic constant difference of elasticities (CDE) expenditure function is implemented that allows for changes in income elasticities when purchasing power parity (PPP)-corrected real GDP per capita changes.

Fertilizers in MAGNET

Sector data

For this paper MAGNET is extended to explicitly account for the three macronutrients: nitrogen (N), phosphorus (P2O5) and potassium (K2O). This method follows the method described in Lampe et al, 2014. To introduce three new sectors in MAGNET that produce fertilizer nutrients N, P2O5, K2O several data sources were used: fertilizer use per crop and country from IFA (international fertilizer association), trade data from BACI ("Base pour l'Analyse du Commerce International" or in English "Database for International Trade Analysis").[1] and cost structure data of the new sectors based on unstructured information on production costs related to N and P2O5 (provided from IFA) and K2O (expert knowledge). Note that fertilizers have both agricultural and non-agricultural uses. In this paper we focus only on the agricultural uses.

We model the three nutrients N, P2O5 and K2O as separate sectors which are produced only so as to be consumed from agricultural sectors (hence only intermediate demand, no final consumption).

As BACI data refers to fertilizer products which contain a specific amount of nutrients, the products are converted into nutrients based on conversion factors provided by IFA. The products considered are those IFA proposed. Price data is also derived from BACI as value exported divided by the quantity of value exported. Regarding prices for our three nutrients we use "reference prices". In detail we use the following fob prices:

- N: HS310210 (Urea)

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[1] "Base pour l'Analyse du Commerce International" (CEPII, 2013).

http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=1

- P_2O_5: HS310530 (DAP)
- K_2O: HS310420 (MOP)

The cost structures of the new fertilizers sectors have been calculated based on production costs provided by IFA (N and P2O5) and expert knowledge (K2O). Note that in most countries the main input of N is gas except for China where the main input is coal, whereas the main input of P2O5 and K2O is other mining products.

As noted above, total demand and trade of fertilizers can be taken from different secondary data sources. However production of fertilizers and domestic demand of fertilizers need to be calculated. Assuming that there are no other uses of fertilizers, domestic demand of fertilizers is calculated as the total demand (based on IFA data) minus the imports of fertilizers (based on BACI data). Then the production of fertilizers can be determined as the calculated domestic demand of fertilizers plus the export of fertilizer (based on BACI data).

Based on 2006 IPCC Guidelines emissions related to the use of N fertilizer are calculated. Both direct and indirect air emissions are taken into account. Air emissions related to the production of fertilizers have been calculated based on data found at the JEC E3-database about emissions and production in kg per nutrient as calculated by MAGNET. The values of emissions per kg of use or production are shown in Table 1.

Table 1 Emissions related to use and production of fertilizers

		gCO2/kg	gCH4/kg	gN2O/kg	gCO2-eq/kg
use	N-fertilizer (kg N)	0	0	13	6479
production	N-fertilizer (kg N)	2827	9	10	5881
production	P2O5-fertilizer (kg P2O5)	965	1	0	1011
production	K2O-fertilizer (kg K2O)	536	2	0	576

Source: JEC E3-database (version 31-7-2008)

MAGNET assumes that fertilizers can be substituted for land in crop production, thereby accounting for extensification vs. intensification of agricultural production. Empirical evidence with regard to the value of the land-fertilizer substitution elasticity is scarce and disperse. A higher value of the substitution elasticity between land and fertilizers would generally result in more pronounced reductions of fertilizer use following an elimination of fertilizer support policies. This would result in lower yields and higher land use. The substitution elasticity between land and fertilizers are set at 0.15 for developed countries and at 0.5 for developing countries.

Apart from the substitution elasticity between land and fertilizer, we also included substitution between the three different nutrients. Due to a lack of reliable data, we assume that this elasticity is equal to 0.5, which is comparable to the elasticity between land and fertilizer. To analyse how sensitive the results are for this parameter we will also include a sensitivity analysis where we substantially reduce this substitution elasticity.

Data and results

GTAP data used

MAGNET is calibrated to version 8 of the GTAP database with base year 2007. The database is aggregated into 22 countries or regions and 35 commodities (Tables A.1 and A.2 in the Annex) to reflect the modelling of fertilizer and biofuel sectors and policies and capture the effects on agricultural markets. This involves identifying the following sectors separately: biofuel feedstocks (such as wheat, coarse grains, sugar cane and sugar beet, crude vegetable oil), livestock (ruminants and non-ruminants), biofuels (ethanol and biodiesel), by-products used as compound feed components (DDGS, oilcakes), the three fertilizer macronutrients (nitrogen, phosphorous and potassium) and the energy sectors (crude oil, natural gas and coal). The regional disaggregation separates countries key to fertilizer markets such as Argentina, Brazil, Canada, China, EU27, India, Indonesia, Russia, and the US, from geographical aggregates.

Support policies for fertilizers

Subsidies to the production and use of fertilizers were transformed into ad-valorem subsidy rates using fertilizer cost information available from the MAGNET database. Where relevant and possible, these rates were calculated separately for nitrogen, phosphate and potassium fertilizers. In most cases, however, these rates are identical across the three macronutrients as fertilizer-specific information was unavailable. The resulting input subsidy equivalents for the main countries subsidising the use of fertilizers in agriculture are shown in Table 2.[2]

Table 2 Fertilizer subsidy rates, per cent of cost

	Input subsidy	Output subsidy
Indonesia		67.9%
India		56% (N) 60% (P and K)
Russia	28.0%	
China	12.5%	

Source: *von Lampe et al. (2014)*

These figures indicate the relevance of fertilizer subsidies to agricultural production in the four countries. With an output subsidy covering more than two-thirds of fertilizer costs, fertilizer support is particularly relevant for Indonesian agriculture. In the case of India, a fertilizer producer support (output subsidy) equivalent was calculated, representing about 56% for nitrogen and 60% for phosphorus and potassium. For Russian crop sectors around one-fourth of total fertilizer costs are covered by governmental intervention.

Fertilizer-related support in China is provided as a comprehensive subsidy on agricultural inputs. Having an important motivation in the role of fertilizers for crop production, it is also related to other inputs. Implemented as an area payment, this support policy is modelled as a ‘land based’ payment and linked to both land and fertilizer use. The amount granted is equivalent to an ad-valorem subsidy of approximately 12.5% of the value of fertilizer and of land in production costs, respectively.

Scenario description

Reference scenario

The reference scenario represents a forward-looking simulation of the world economy until 2025. It is based on a number of assumptions for which other sources were used. Most importantly, these include

2. To avoid inconsistencies in subsidy rates across crops, the input rates which were available in the original MAGNET database for the aggregate ‘chemicals’ have been adjusted accounting for the subsidy rates relative to fertilizer policies.

assumptions on future developments in GDP and population, price paths for key fossil-energy carriers (crude oil, coal and natural gas), and policies in the fertilizer sectors.

Estimates of real GDP and population growth for the period 2007-2025 are taken from OECD-FAO (2013)[3]. This scenario assumes that world economic growth will be sluggish over the short-term, and then recover after 2013 and expand by about 4.2% annually. The recovery is assumed to have two-speeds: a first period in which growth will be modest in developed countries, reflecting the post-economic crisis effects, followed by a second period of more rapid growth in both emerging and developing countries, driven by private demand. World population growth is expected to slow between 2013 and 2025 to only 1% annually. Population is expected to grow more in developing countries, and in particular in African countries, growing over 2.3% annually whereas it is expected to decline in Japan and in Russia by about 0.2% annually. Growth in yields is taken from the IMAGE model suite (Kram and Stehfest, 2012; OECD, 2012) and is based upon FAO projections up to 2030 (Bruinsma, 2003).World crude-oil prices are assumed to develop as reported in EIA (2015) and are assumed the market rebalances at $80/bbl in 2020, with further increases in price thereafter. World natural gas and world coal prices for the period 2007-2010 are taken from the World Bank (2012) and for 2011-2025 from the US EIA (2015).

Developments in covered fertilizer policies after 2007, as listed in OECD (2013b) or programmed in existing legislation, have been accounted for in the baseline scenario. Otherwise, the subsidy rates listed in Table 2 are assumed to remain constant throughout the reference scenario.

Results

A reference scenario to 2025

Projections of the reference scenario suggest that structural changes, i.e. a decline in the agricultural contribution to total income and employment, will continue. The decreasing share of agriculture in income is caused by demand for agricultural products being rather insensitive to income growth and by a relatively high rate of technical change in the agricultural sector, continuing past observed trends. The first effect implies that consumers spend increasingly less of their income on agricultural products as incomes rise; the second implies that the same amount of agricultural products can be produced with fewer inputs. The share of primary agriculture[4] in GDP continues to fall worldwide between 2010 and 2025 (Figure 3). The importance of agriculture in GDP is lower in developed countries such as Canada, the EU and USA and higher in developing and emerging economies such as Argentina, China, India, Indonesia, and Russia. Structural change is quicker in the latter countries, implying that more labour will be released from the agricultural sectors in these countries. In consequence, particularly regions dominated by agricultural activity and with little employment opportunities in other sectors may thus require adjustment measures reducing problems of unemployment and income losses.

3. OECD-FAO (2013) projects up to 2022. For the years 2023-2025, we extrapolate the trends of period 2017-2022.

4. Hereafter primary agriculture refers to the first ten commodities listed in Table A.2.

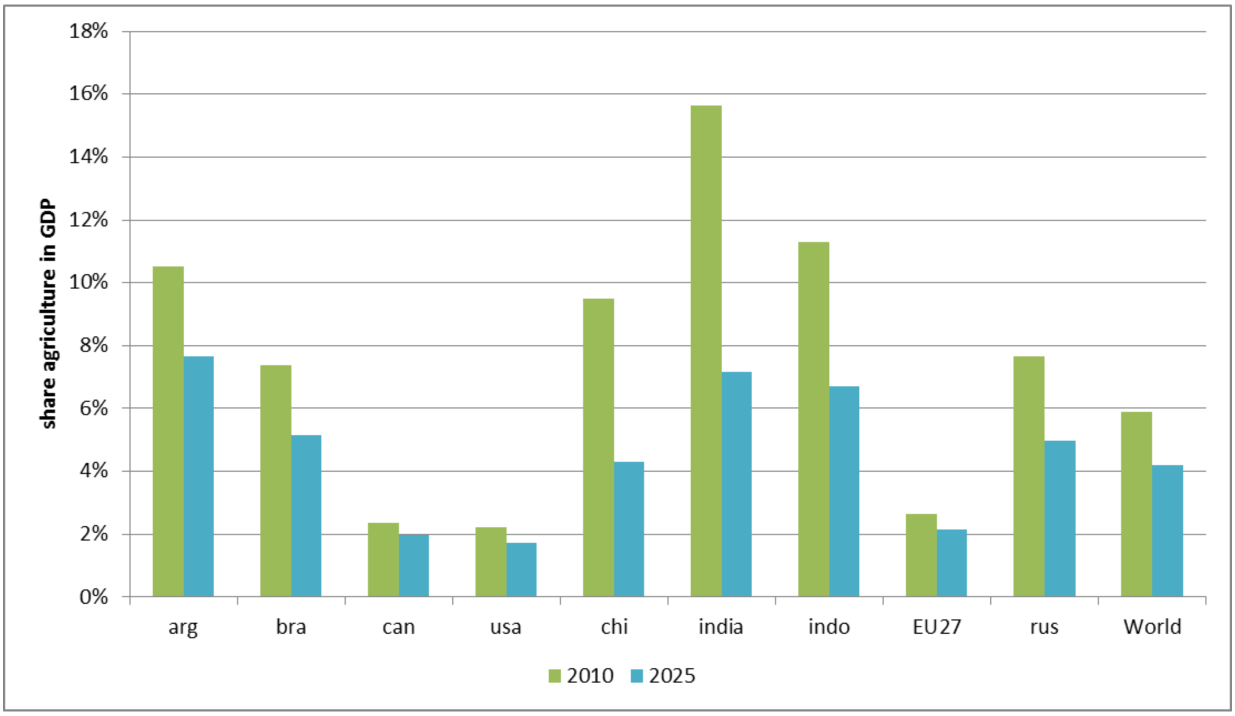

Figure 3 Share of agriculture in GDP, reference scenario

Source: MAGNET simulation results.

Fertilizer use in agriculture increases between 2010 and 2025 by the same rates as fertilizer production, suggesting the intensification of agricultural production. Intensity measured as the use of fertilizer per square kilometre is modest for most countries as Figure 4 Use of fertilizer (in million 2010 dollars per Figure 4 shows. The use of fertilizer is expected to increase slightly in most countries, signifying an modest intensification of agricultural production. The fertilizer use in India is already quite high in 2010 compared to other countries due to the extensive fertilizer support system present in this country. By 2025 the intensity is expected to further increase.

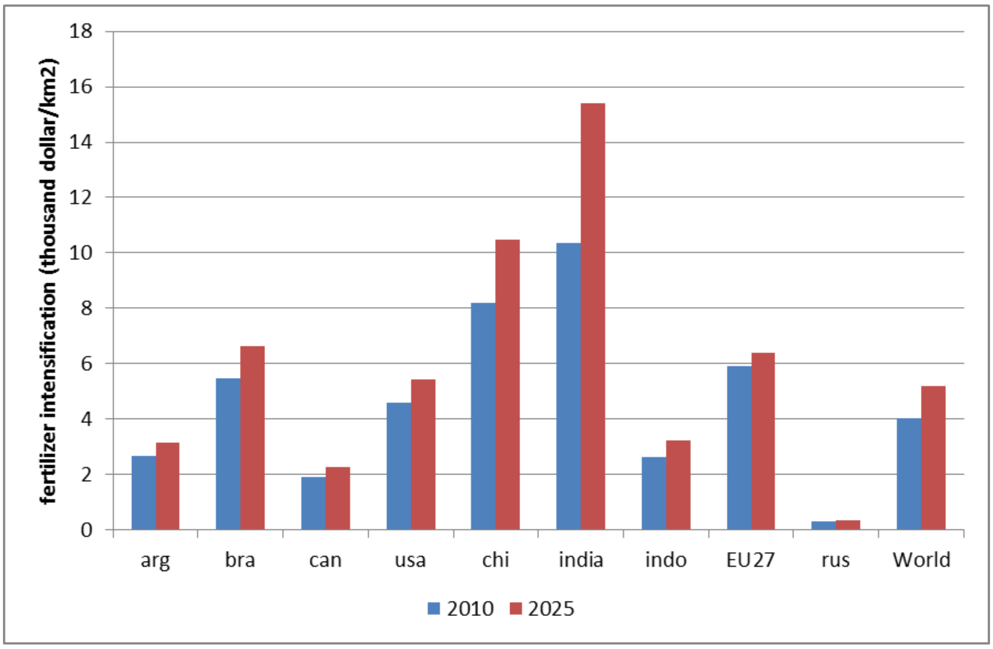

Figure 4 Use of fertilizer (in million 2010 dollars per km2), reference scenario

Source: MAGNET simulation results

As intensities increase, the use of all three fertilizer macronutrients is projected to grow by more than the rate of agricultural commodities. The global use of nitrogen, phosphorous and potassium is assumed to grow by 3%, 2% and 2% p.a. respectively. The higher growth rate of nitrogen is due to the decreasing gas price. As mentioned above, natural gas represents the bulk in the production costs of nitrogen fertilizers. Production of phosphorous and potassium, which are mining products, is less affected by changes in natural gas prices. In consequence, nitrogen fertilizer prices tend to fall relative to phosphorous and potassium prices. Figure 5 shows the use of fertilizer per nutrient by country. The increase in the use of nitrogen is potentially problematic as nitrogen is the one fertilizer nutrient that causes CO2 emissions due to use in crop sectors.

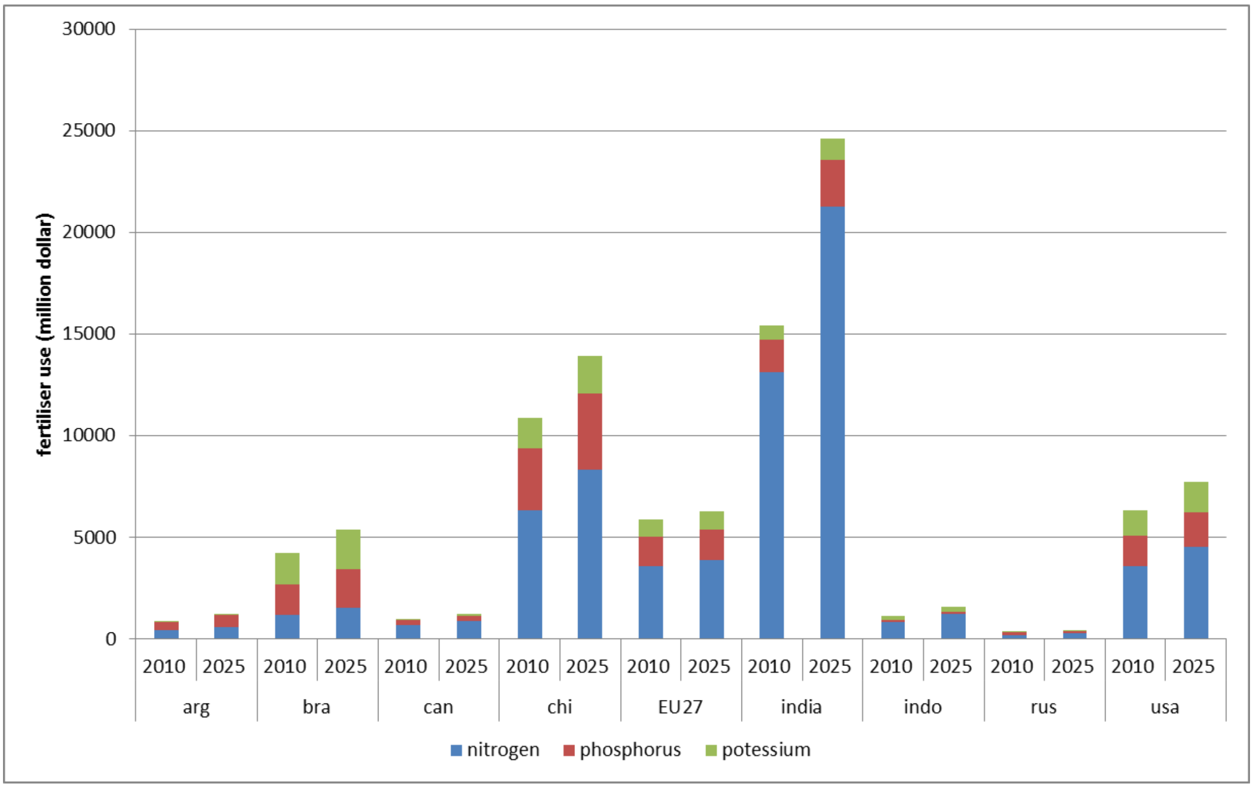

Figure 5 Use of fertilizer per nutrient (in million 2010 dollar), reference scenario

Source: MAGNET simulation results

Impacts of removal of fertilizer support policies

A removal of fertilizer subsidies, both those paid to fertilizer producers and those to farmers, increases the cost of fertilizer use for farmers. Figure 6 shows the impact of the policy shock (removal of all fertilizer support) on fertilizer demand. The use of fertilizer decreases in the four countries with extensive fertilizer subsidies: China, India, Indonesia, and Russia. Surprisingly in India and Indonesia, the use of potassium and in the case of Indonesia phosphorus increases. This is a trade effect. In India and Indonesia, nitrogen is mostly produced locally and potassium and phosphorus are imported. By removing the fertilizer support policies, the domestically produced nitrogen becomes less cost attractive than the imported phosphorus and potassium. Thus these countries replace nitrogen with potassium and phosphorus. Note that we assume a reasonably large substitution elasticity between the three fertilizer nutrients. If these nutrient are less substitutable, this effect is less likely to occur and this can potentially also increase the cost of removing the support policies. The impact of the substitution elasticity between the three different nutrients on the results is further explored in the sensitivity analysis section.

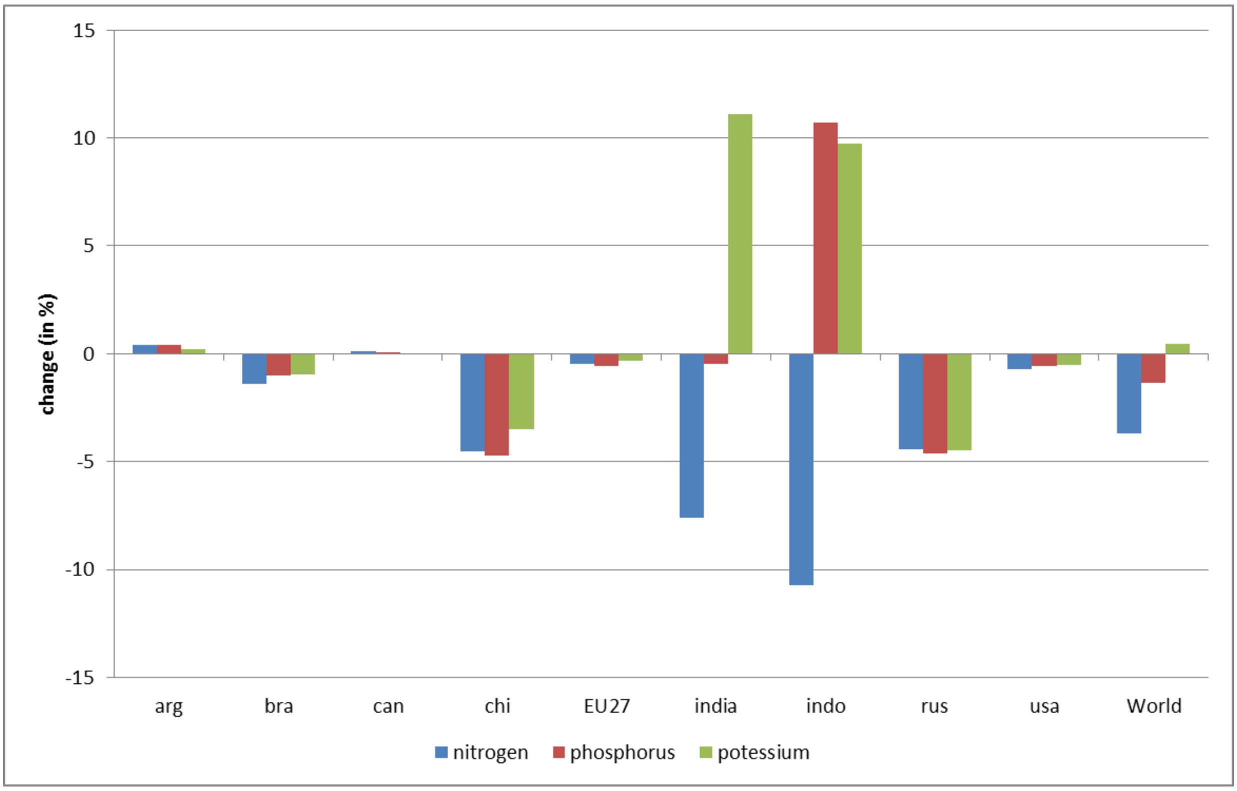

Figure 6 Impacts removal fertilizer support policies on fertilizer use, percentage change to reference scenario, 2025

Source: MAGNET simulation results

The effects on agricultural production and price differ by region as Figure 7 shows. In China, the input-related area payments (modelled to be linked to both land and fertilizer use) have a relatively strong effect on agricultural production. Overall crop production declines by 1% and the price increases by 5%. In India and Indonesia, fertilizer subsidies are paid directly to the fertilizer industry, with the output subsidies on fertilizers in India amounting to 56%-60% of production costs, whereas those paid in Indonesia correspond to as much as two-thirds of production costs (Table 2). Abolishing these subsidies increases fertilizer prices and leads to higher production costs for farmers, who respond by decreasing agricultural production slightly and by increasing the price of agricultural products. The production effects are less significant in Indonesia where the more expensive fertilizers can be substituted more easily by additional land use. Abolishing the fertilizer subsidies has a positive impact on countries which did not implement a fertilizer subsidy. Those countries benefit from the lower supply of agricultural products from especially China and increase their agricultural production and agricultural trade.

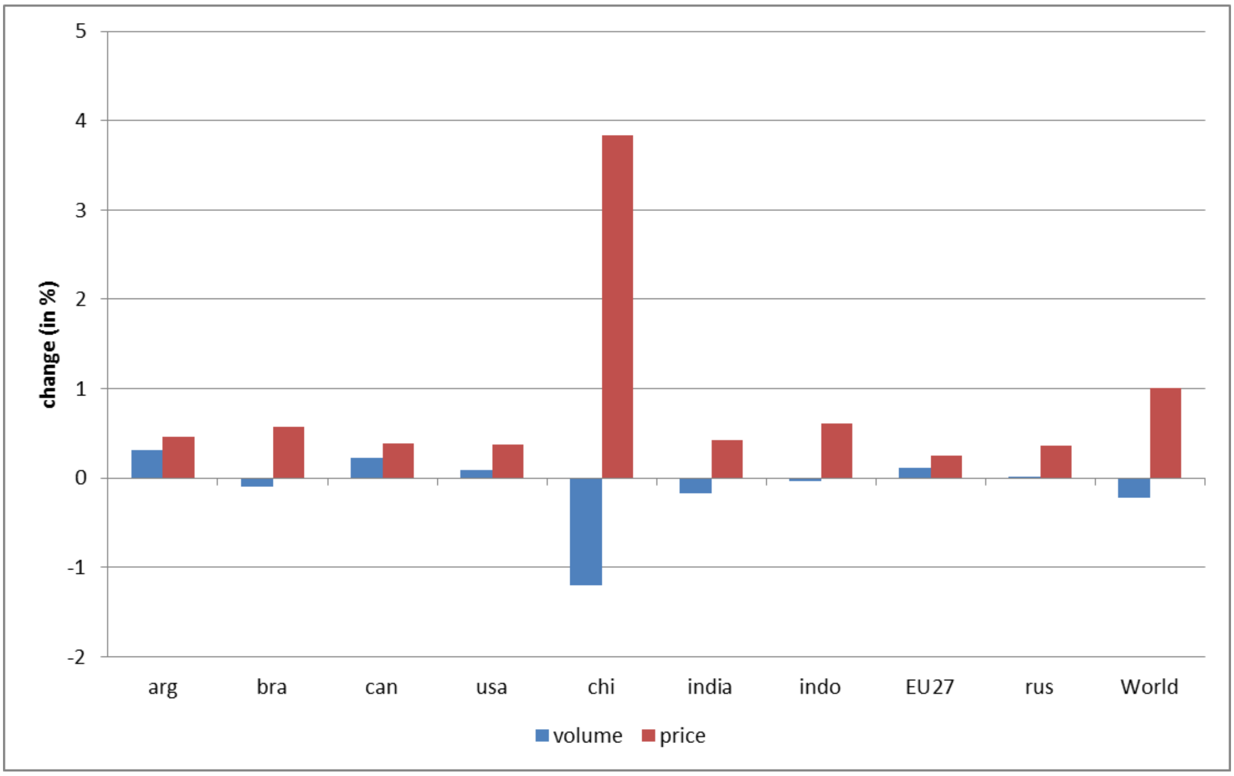

Figure 7 Impacts on removal fertilizer support policies on agricultural production and price, percentage change to reference scenario, 2025

Source: MAGNET simulation results

The results so far are as expected, the removal of support policies reduces the use of fertilizers and in a limited way reduces the production of agricultural products. We will further explore how the removal of fertilizers support measures impacts the world on three key areas of concern: welfare, environment and food security

Welfare

GDP is often reported in country comparisons as a welfare measure and as indication for compensation payments. Kohli (2004), however, demonstrates that when one country experiences some terms of trade improvements this welfare indicator may be in fact misleading as it underestimates the increase of real domestic income and welfare. Real GDP is unable to capture the beneficial effect for an economy of an improvement in its terms of trade (say an increase in export or decrease of import prices) as it focuses only on production possibilities. The welfare impacts are better measured by the equivalent variation which is the change in wealth, at current prices, that would have the same effect on consumer welfare as would the change in prices, with income unchanged. We use an adjusted for the MAGNET model version of the welfare decomposition method developed by Huff and Hertel (2001). As both GDP and equivalent variation are used as indicators for compensation we present both variables and use the equivalent variation as a method to decompose the overall welfare effect in their main components.

Figure 8 shows the impact the removal of fertilizer subsidies has on GDP. Overall the impact on GDP is slightly positive. Of the fertilizer subsidizing countries, India and Indonesia show a slight GDP gain and China and Russia show a slight GDP loss. Indonesia shows the highest net gain due to the removal of fertilizer support policies.

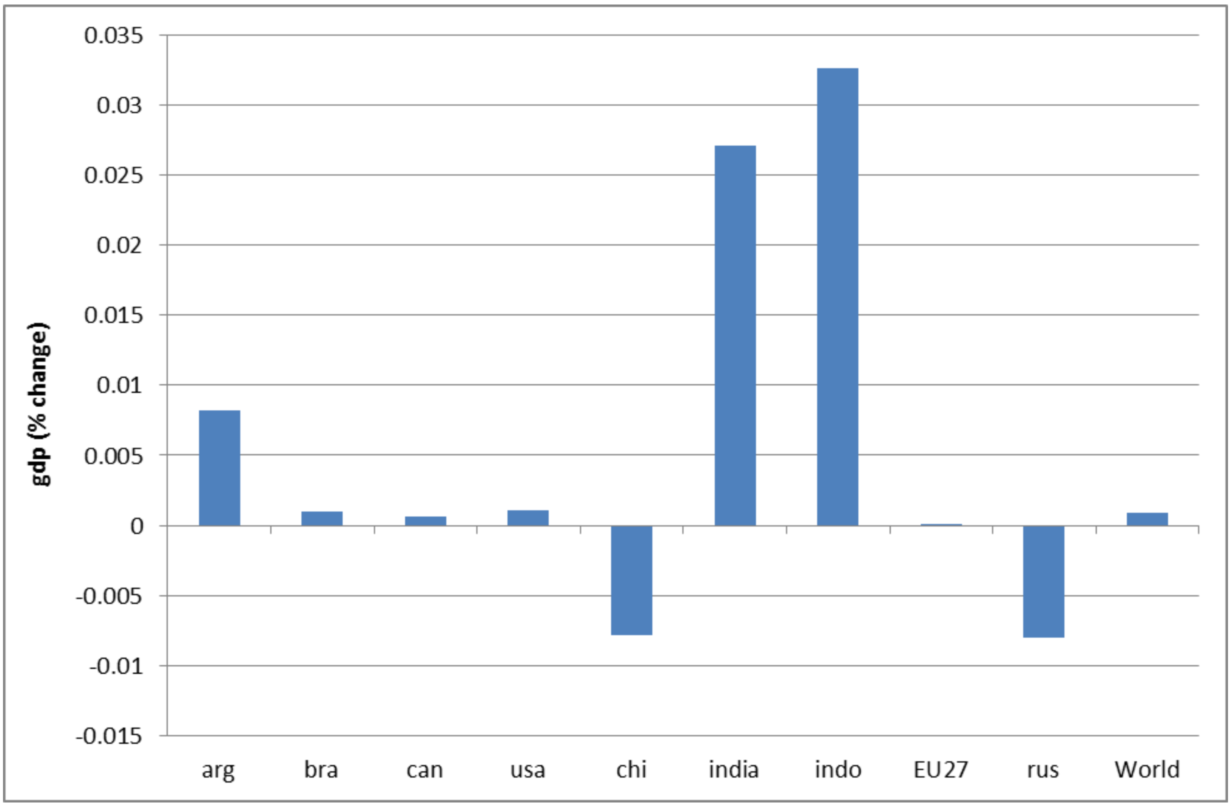

Figure 8 Impact removal fertilizer support policies on GDP, percentage change to reference scenario, 2025

Source: MAGNET simulation results

The decomposition of the welfare (Figure 9) shows the difference in welfare impact between India and Indonesia on the one hand and china and Russia on the other hand. In both India and Indonesia the allocation effect is positive. This indicates that due to the support policies the use of fertilizer was too high. Removing the subsidy, removes this distortion leading to a positive allocation effect. The removal of fertilizer policies further imply that more land resources are used for agriculture and this results in positive contribution of the endowment effect. India as a food net importer shows a deterioration of the terms of trade as food prices increases and more fertilizers need to be imported. Indonesia as a net food exporter does not see its trade balance deteriorate which leads to a slightly higher overall welfare increase.

In China, the positive allocation effect is overshadowed by the negative endowment impact. Because China subsidized both land and fertilizer use, after the removal of the fertilizer subsidies less land resources are used for agriculture and this results in a negative contribution of the endowment effect. Like India, China is a net importer of food and thus the trade balance also deteriorates for China due to the increased food prices. All in all, these impact lead to a negative welfare effect for china.

In Russia, surprisingly the allocation effect is negative. While the removal of the fertilizer subsidy, results in a positive allocation effect for fertilizer use, this effect is overshadowed by a larger use of gas. Russia which possess relatively cheap gas, starts exporting nitrogen to India and Indonesia after the removal of fertilizer support policies. This increased use for gas for fertilizer production leads to a negative allocation effect and thus a slightly negative welfare effect.

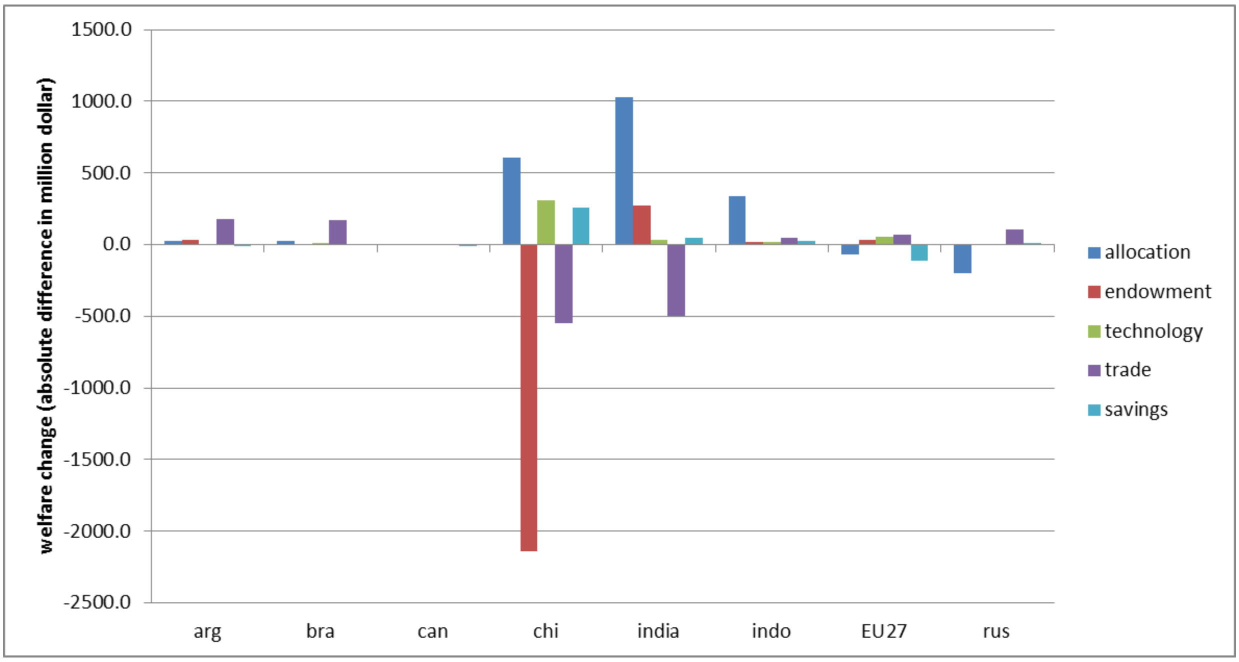

Figure 9 Welfare decomposition (measured as equivalent variation), absolute difference to reference scenario (million dollar), 2025

Source: MAGNET simulation results

Environmental impact

The reduced use of nitrogen leads to less GHG emissions as Figure 10 shows. This impact is especially noticeable in India and Indonesia. In Russia the total emissions slightly increase. While emissions related to nitrogen use decrease in Russia, emission related to fertilizer production increase. As said before, Russia starts exporting nitrogen to India and Indonesia which leads to more emissions related to nitrogen production. Emissions in non-fertilizer supporting countries slightly increase. Due to a lesser demand for fertilizers from China, India, Indonesia and Russia, the world market price of fertilizers decreases leading to a slight intensification of fertilizer use in the rest of the world. Overall however the removal of fertilizer support measures has a positive impact on the environment, worldwide GHG emissions will decline with almost 13 million tons CO2 equivalent.

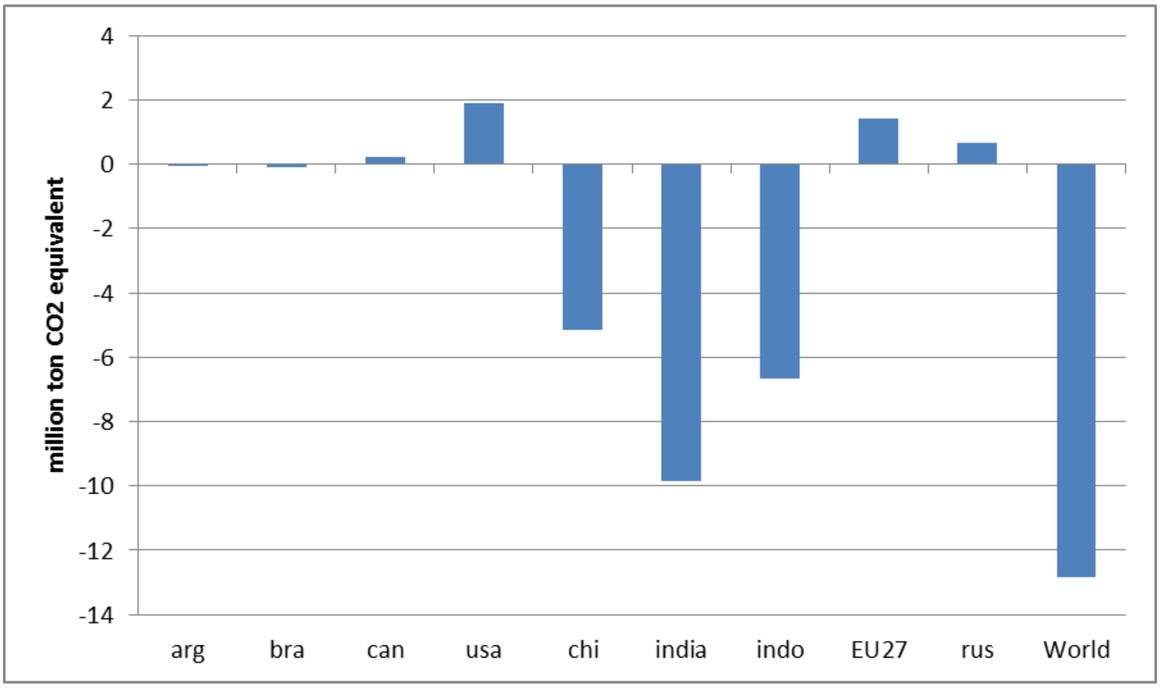

Figure 10 Impacts on total emissions, absolute difference to reference scenario (in million ton CO2 equivalent), 2025

Source: MAGNET simulation results.

Theoretically if more land is used for agriculture this land is probably converted from forestry and this frees up carbon which adds to climate change. Therefore land use for agriculture can be seen as an environmental indicator. Abolishing fertilizer policies has only a modest effect on global agricultural land use. Figure 11 shows the effects of removing the fertilizer policies on agricultural land use. In China land demand even decreases as agriculture production decreases. This leads to slightly less land demand worldwide. Theoretically this land could be converted to forestry as a carbon sink adding to the reduced emissions of the previous graph.

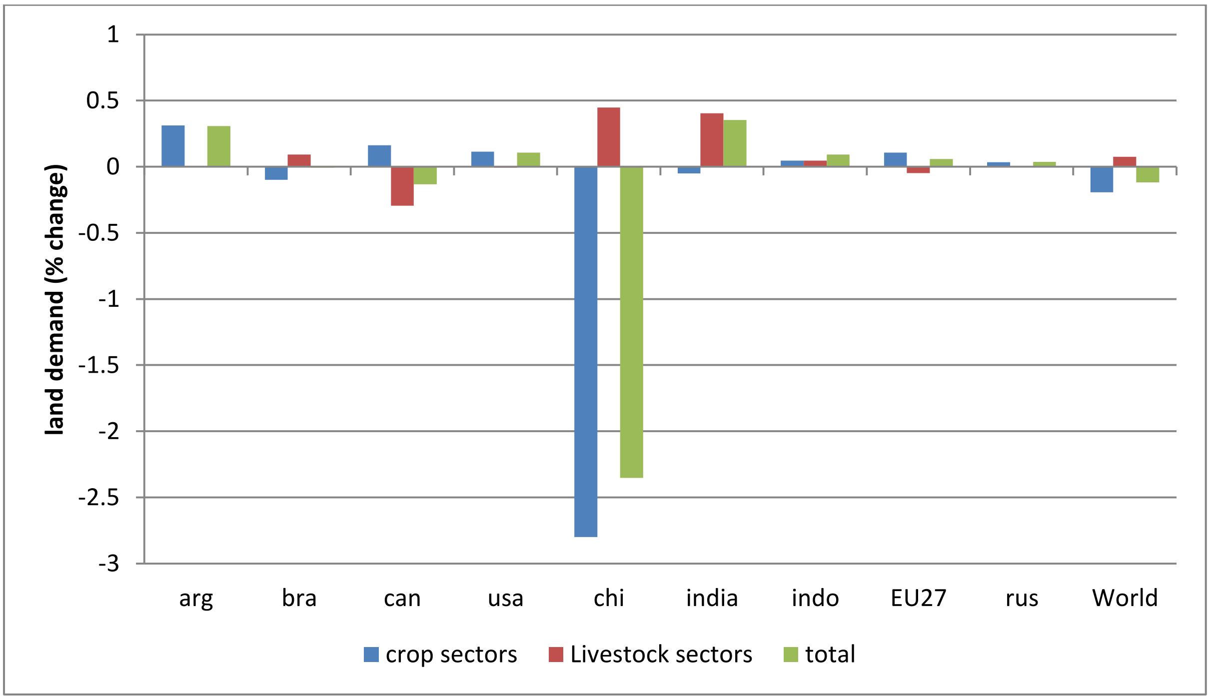

Figure 11 Impacts on land use, percentage change to reference scenario, 2025

Source: MAGNET simulation results.

Food security

While the welfare and environmental impacts overall showed quite positive results for abolishing fertilizer support policies, the food security impact is less positive. Figure 12 shows the results for the food security indicator. This indicator is calculated as change in cereal prices divided by the change in wages of unskilled labor and represents the food purchasing power of the lower income households. Figure 12 shows the food purchasing power of both the rural and urban households. Overall the food purchasing power declines. In most countries this impact is modest. Worldwide the food purchasing power declines by about 1%. The biggest impact is in China. In this country the price of food increases the fasted leading to 5% less food purchasing power.

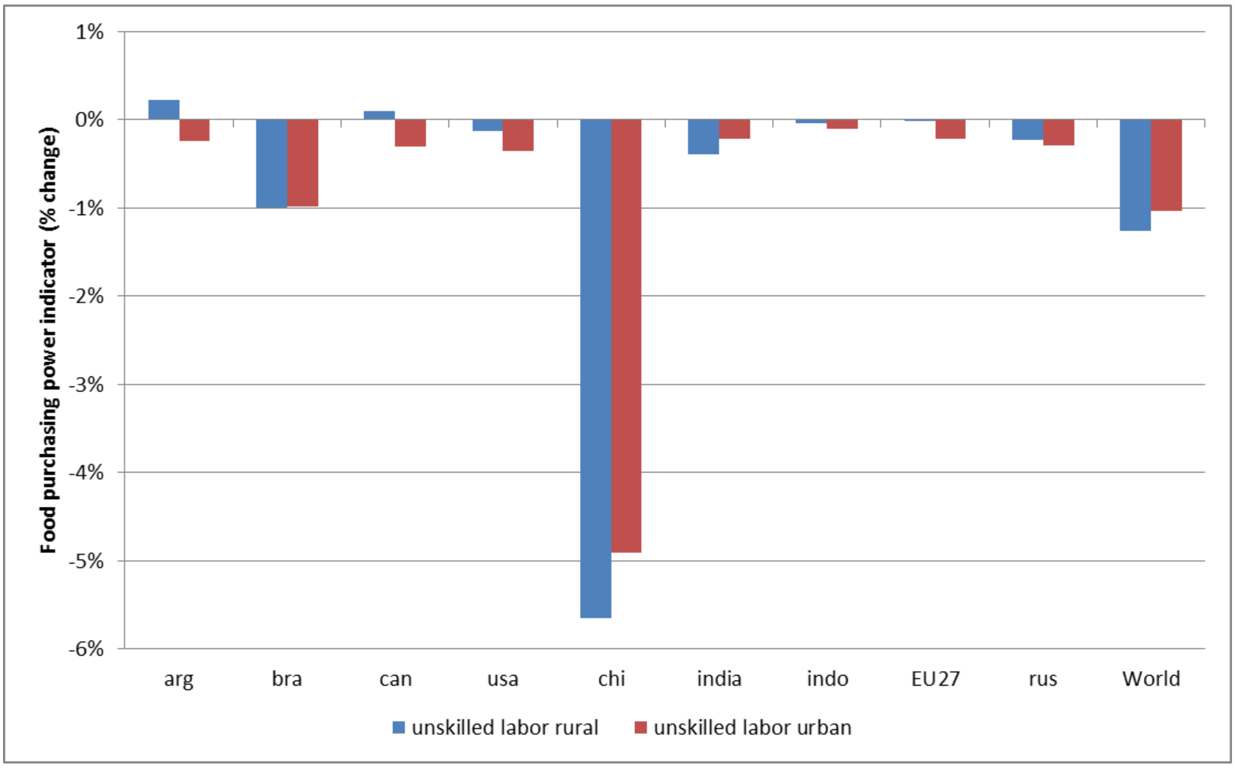

Figure 12 Impacts on food security, percentage change to reference scenario, 2025

Source: MAGNET simulation results.

Sensitivity Analysis

It can be expected that the results will be quite sensitive to the assumption made for the substitution elasticity between the different fertilizer nutrients. In the results described above a substitution elasticity of 0.5 was assumed. In a sensitivity analysis we changed to value of this elasticity to 0.1. Figure 13 shows the change in results with the lower substitution elasticity for both GDP and GHG emissions. In the base scenario, countries could substitute away from the more expensive nitrogen to potassium and phosphorus. In this sensitivity scenario they hardly have the option to substitute between nutrients, instead to reduce costs they will need to reduce fertilizer consumption. As a results, the welfare impact of the policy change is slightly less positive. The biggest difference however is in the environmental impact. As the crop sectors are more or less forced to keep using the nutrients in the same proportion, the GHG emissions decline less. Overall emissions only decline by about 9 million tons CO2 equivalent versus 13 million tons CO2-eq in the base scenario, about 30% less.

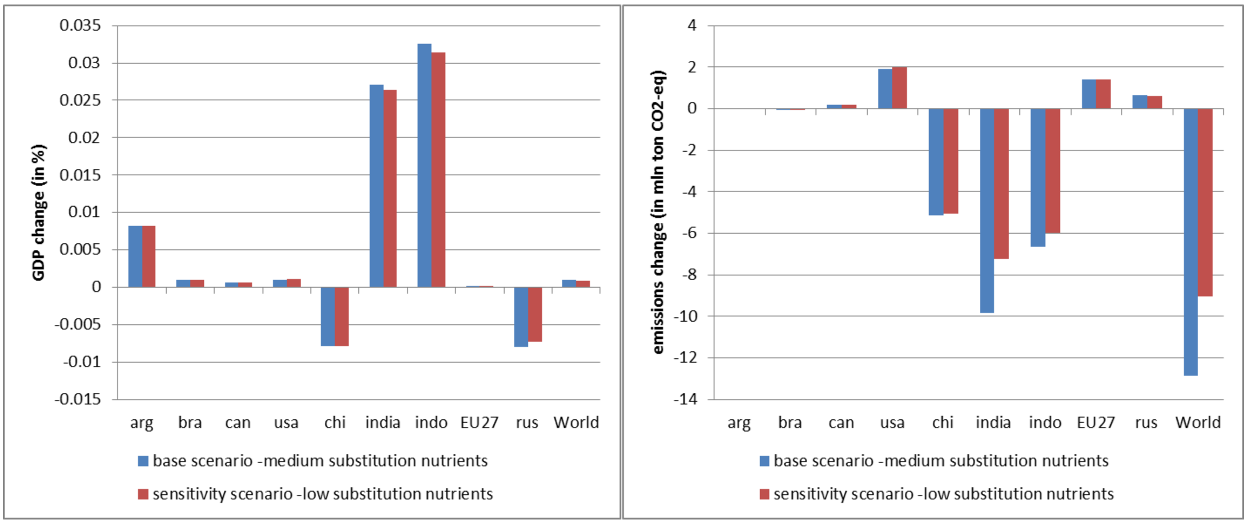

Figure 13 Impact sensitivity analysis, percentage change to reference scenario, 2025

Source: MAGNET simulation results.

The food purchasing power worsens a bit more if hardly any substitution is allowed between the three fertilizer nutrients. Especially in Indonesia and India, food prices increase causing the lower income households to lose as Figure 14 shows. Overall the impact is however quite small, worldwide the extra loss of food purchasing power is about -0.25%.

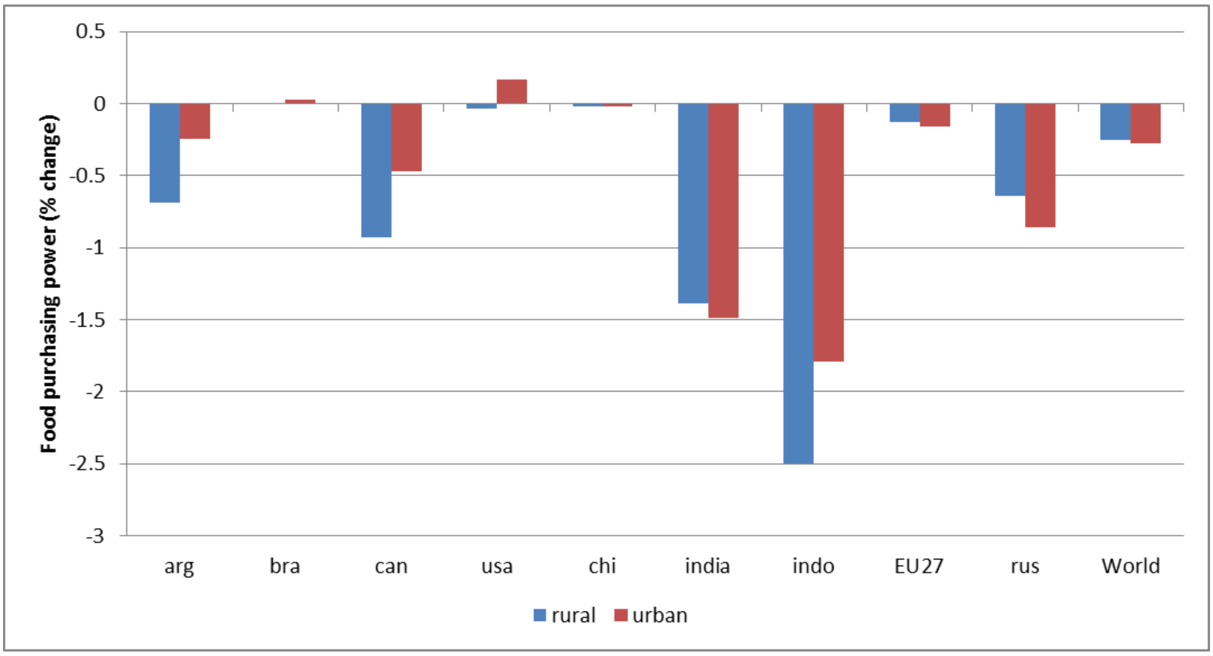

Figure 14 Impact sensitivity analysis food purchasing power, percentage change sensitivity scenario versus base scenario, 2025

Source: MAGNET simulation results.

Conclusions

The computable general equilibrium model MAGNET was upgraded to include individual fertilizer markets – compared to an earlier OECD study (von Lampe et al., 2014), the model now covers the three macronutrients separately, allowing for a more detailed anaylsis of policies, markets and impacts. Besides that the model now also includes GHG emissions related to fertilizer use and production. Based on a reference scenario involving basic assumptions on a number of other key variables, including but not limited to developments in population and GDP by country, the model was used to generate a counterfactual scenarios towards 2025 allowing the generation of implied policy impacts on agricultural markets, fertilizer markets and incomes in a forward-looking manner.

Information about fertilizer policies were collected in a database compiled in collaboration between the OECD Secretariat, member countries (and some key partner countries) governments and external consultants (OECD 2013b). Significant subsidies within the fertilizer sector have been identified in four countries, mainly provided more or less directly to farmers to offset high fertilizer costs (Indonesia, Russia and China), but also given to fertilizer producers to counter high production costs, particularly in the context of high energy prices (India). These subsidies represent 12.5% of fertilizer and land costs in China, and range from 28% of fertilizer production costs in Russia to 68% in Indonesia.

As suggested by economic reasoning, fertilizer support policies result in lower fertilizer costs for crop farmers and hence increased agricultural production. Average prices would change relatively little if fertilizer support policies were eliminated. Due to higher agricultural production costs, consumption decreases which in turn dampens the increase in agricultural prices. The impact of fertilizer support policies was analysed on three main areas of concern: welfare, the environment and food security.

Subsidizing fertilizer use and production overall causes a slight welfare loss. The non-subsidizing countries will suffer a welfare loss on the one hand due to a decrease of world food prices which leads to a deteriorating trade balance (for the net food exporters) and on the other hand due to higher world fertilizer prices caused by increased demand for fertilizers in the fertilizer subsidizing countries. Even in some countries that subside fertilizers welfare may decline due to overuse of fertilizerswhich cause a negative allocation impact..

While fertilizers are not the main contributor to GHG emissions, worldwide fertilizers contribute about 1% of total GHG emission, fertilizer support policies do lead to more GHG emissions worldwide and thus contribute to climate change. Removing all fertilizer support policies could reduce GHG emissions by 13 million tons CO2 equivalent.

Fertilizer support policies do lead to higher food security. World food prices decline due to fertilizer support policies which will lead to improved food security for the lower income households. Overall this impact is very low. Food prices are only modestly impacted by the fertilizer support policies which leads to only a modest impact in the food security indicator in most countries. Only in China there is a significant gain in food security due to the fertilizer support policies.

Due to a lack of reliable data assumptions needed to be made about the substitution between different fertilizer nutrients. Because this substitution elasticity potentially could have a lot of impact on the results a sensitivity analysis was done for the parameter. The results show that while this parameter has some impact on the results, the overall trend stays the same. Even with less substitution between the fertilizer nutrients both welfare and environment decline worldwide due fertilizer support policies but food purchasing power increases worldwide.

This analysis is subject to a number of caveats, in addition to the general one that models are a simplified representation of real-world markets. Given that the model is comparative-static with a medium-term framework, the results shown in this report refer to impacts after adjustments have taken place. Short-term implications of sudden policy shifts are likely to be more pronounced than suggested by the model results. Furthermore, the Armington specification of trade flows tends to make the model conservative with respect to the structure of international trade.

More research should be done to further explore the impact fertilizer use has on yields in different regions. We have tried to include this by differentiating the substitution elasticity between land and fertilizers for developed and developing countries but this should preferably be estimated by region.

The scenario we ran in this paper is quite extreme and it may very well be true that subsidizing fertilizer use in regions with nutrient poor crop land, like for example Africa and only removing subsidies in countries with overuse of fertilizer may be even more beneficial.

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Annex

Table A.1. Regional aggregation

Regions	Mapping with GTAP(v8.1) regions[1]
Argentina	Arg
Australia	Aus
Brazil	Bra
Canada	Can
Chile	Chl
China, Hong Kong, Mongolia and Taiwan	chi, hkg, mng, twn, xea
European Union (27 member states)	aut, bel, bgr, cyp, cze, deu, dnk, esp, est, fin, fra, gbr, grc, hun, irl, ita, ltu, lux, lva, mlt, nld, prt, pol, rou, svk, svn, swe
India	Ind
Indonesia	Idn
Japan and Korea	jpn, kor
Malaysia	Mys
Mexico	Mex
Morocco	Mar
Russia	Rus
South Africa	Zaf
Turkey	Tur
USA	Usa
Rest of Africa	ben, bfa, bwa, civ, cmr, egy, eth, gha, gin, ken, mdg, moz, mus, mwi, nam, nga, rwa, sen, tgo, tun, tza, uga, xac, xcf, xec, xnf, xsc, xtw, xwf, zmb, zwe
Rest of Asia	are, arm, aze, bgd, bhr, blr, geo, irn, isr, kaz, kgz, khm, kwt, lao, lka, npl, omn, pak, phl, qat, sau, sgp, tha, ukr, vnm, xsa, xse, xsu, xws
Rest of Central and South America	bol, col, cri, ecu, gtm, hnd, nic, pan, per, pry, slv, ury, ven, xca, xcb, xsm
Rest of Europe	alb, che, hrv, nor, xee, xef, xer
Rest of Oceania	nzl, xoc

Note: 1: A full description of the regions in the GTAP database v8.1 is given in https://www.gtap.agecon.purdue.edu/databases/regions.asp?Version=8.211

Table A.2. Commodity aggregation

Commodities	Mapping with GTAP(v8.1) sectors[1]
Paddy rice	Pdr
Wheat	Wht
Coarse grains	Gro
Oilseeds	Osd
Sugar cane and sugar beet	c_b
Vegetables, fruit, nuts	v_f
Other crops	ocr, pfb
Ruminants	ctl, wol
Non-ruminants	Oap
Raw milk	Rmk
Meat from ruminants	Cmt
Meat from non-ruminants	Omt
Dairy products	Mil
Sugar	(sgr)[2]
Crude vegetable oil	(cvol)[2]
Oilcakes	(oilcake)[2]
Vegetable oil (refined)	(vol)[2]
Food products	pcr, b_t, (ofd)[2]
Other compound animal feed	(feed)[2]
Fishing	Fsh
Forestry	Frs
Crude (fossil) oil	Oil
Petroleum, coal products	p_c
Biodiesel	(biod)[2]
Biogasoline	(biog)[2]
Distiller's Dried Grains with Solubles	(ddgs)[2]
Natural gas	Gas
Coal	Coa
Electricity	Ely
Nitrogen	(N)[2]
Phosphorous	(P2O5)[2]
Potassium	(K2O)[2]
Rest of chemical products	(crp)[2]
Other industry	ele, fmp, i_s, lea, lum, mvh, nfm, nmm, ome, omf, omn, otn, ppp, tex, wap
Services	atp, cmn, cns, dwe, isr, obs, ofi, osg, otp, ros, trd, wtp, wtr

Notes: 1: A full description of the commodities in the GTAP database (v8.1) is given in https://www.gtap.agecon.purdue.edu/databases/v8/v8_sectors.asp

2: Commodities in brackets have been introduced to MAGNET to better reflect biofuels, fertilizers and the animal feed sectors and are not covered explicitly as disaggregated commodities in the GTAP database.