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Fertiliser and Biofuel Policies in the Global Agricultural Supply Chain

IMPLICATIONS FOR AGRICULTURAL MARKETS AND FARM INCOMES

Martin von Lampe,

Aikaterini Kavallari,

Heleen Bartelings,

Hans van Meijl,

Martin Banse,

Joanna Ilicic-Komorowska,

Franziska Junker,

Frank van Tongeren

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Comments are welcome and may be sent to tad.contact@oecd.org.

Abstract

FERTILISER AND BIOFUEL POLICIES IN THE GLOBAL AGRICULTURAL SUPPLY CHAIN: IMPLICATIONS FOR AGRICULTURAL MARKETS AND FARM INCOMES

by

Martin von Lampe, OECD, France
Aikaterini Kavallari, LEI-WUR, The Netherlands
Heleen Bartelings, LEI-WUR, The Netherlands
Hans van Meijl, LEI-WUR, The Netherlands
Martin Banse, TI, Germany
Joanna Ilicic-Komorowska, OECD, France
Franziska Junker, TI, Germany
Frank van Tongeren, OECD, France

This report analyses policies along the agricultural supply chain, in particular support measures for fertilisers and for biofuels. It uses the OECD Fertiliser and Biofuel Support Policies Database that covers polices in 48 countries (including the EU and its Members) and assesses the market effects of these policies with a computable general equilibrium model, MAGNET. This report finds that biofuel support policies generate additional demand for feedstock commodities and, therefore, higher incomes for crop farmers in subsidising and non-subsidising countries. In contrast, these policies increase costs to downstream industries, including livestock farmers, and to consumers. Fertiliser support policies reduce crop production costs and hence increase yields, production and incomes for crop farmers in subsidising countries. However, they lower crop farm incomes abroad, while livestock farmers in both country groups face lower feed costs and, in consequence, lower livestock prices.

Keywords: Fertiliser support policies, biofuel support policies, fertiliser markets, biofuel markets, energy prices, agriculture, agricultural markets, farm incomes, land use, computable general equilibrium model, quantitative analysis.

JEL: D58, O13, Q11, Q17, Q18, Q42

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Executive Summary

Agricultural markets and incomes are affected by policies in sectors along the agricultural supply chain. Upstream and downstream industries have strong links to the primary agricultural sector, and understanding the implications of policies for farmers' decisions and incomes requires broadening the view beyond policy transfers directly to the agricultural sector.

This study looks closely at policies related to two key sectors along the agricultural supply chain. Fertilisers represent a key input into crop production. Increasingly, high energy prices and limits to mining resources have resulted in increased fertiliser costs for farmers, and several emerging economies have identified fertilisers as an important angle to improve agricultural production and incomes. Downstream from the agricultural sector, the production of biofuels has generated a significant new market for agricultural commodities — particularly, but not exclusively in North America, Brazil and Europe — and much of the increased production and use of biofuels has been stimulated by policy incentives, motivated by a variety of perceived or actual benefits.

For both sectors, a multitude of policies has been identified in a new OECD database on fertiliser and biofuel support policies (OECD, 2013b). Most importantly, subsidies to the fertiliser industry aim at reducing fertiliser prices in India and Indonesia, while subsidies to fertiliser users help farmers in the Russian Federation and China. In these four countries, public support is estimated to reduce fertiliser costs to farmers by between 5% and 68% below production costs. On the biofuel side, support to consumers — notably in the form of tax rebates or exemptions — is found to be widely applied in most of the countries covered, with government-mandated blending of biofuels with petroleum fuels ("biofuel mandates") also driving biofuel use in many of them.

Based on forward-looking simulations to 2025, and using an amended version of the computable general equilibrium model MAGNET, the calculations show that support policies in these two sectors can have significant effects on agricultural production, prices and incomes. Biofuel support policies generate additional demand for feedstocks, which translates into higher incomes for crop farmers – both in subsidizing and to a lesser degree in other countries – but higher costs for downstream industries, including livestock farmers, and consumers. Fertiliser policies reduce crop production costs, increase yields and result in expanded production, resulting in higher incomes for crop farmers in subsidizing countries but lowering incomes for crop farmers abroad. In contrast, livestock prices are affected only moderately: generally higher feed costs resulting from biofuel support policies raise livestock prices slightly. Fertiliser subsidies, where they are applied, tend to lower feed costs and hence reduce livestock prices. With the exception of the effects of large fertiliser support in India, changes to livestock prices remain below 1%.

The analysis shows that these results are driven by two distinct features of the policies looked at: fertiliser subsidies have comparatively strong effects on agricultural markets, domestically as well as internationally. By reducing crop production costs in countries that apply fertiliser subsidies, they disadvantage crop farmers in other countries. Biofuel policies, and in particular biofuel mandates, lift global demand for crops and are found to have comparatively strong positive effects on global farm incomes. Farm incomes are found to be increased globally by about 1% as a consequence of the combined effects of biofuel and fertiliser policies, with substantial variation across countries.

The analysis also discerns the dollar-for-dollar effect of the policies on farm incomes. This shows that, globally, a dollar spent on fertiliser subsidies raises farm incomes by about a tenth of a dollar, much less than the 0.9 dollars income effect from a dollar spent on biofuel policies.

The estimates show that all fertiliser and biofuel support policies combined may raise the global production of wheat, coarse grains, oilseeds and sugar crops by between 1% and 7%. Agricultural land use is generally expanded somewhat in countries supporting biofuel production and use, but reduced in countries providing fertiliser subsidies. While average prices for rice, sugar crops and wheat decrease by up to 6% as a result of increased fertiliser use and higher yields, the effect is dampened for coarse grains and oilseeds due to their use for biofuel production.

The implications for markets and incomes depend significantly on the market environment in which the support is provided. With lower energy prices the impact of fertiliser and biofuel support policies on markets and incomes becomes larger. The support element implied by the biofuel mandate increases with larger differences in the production costs between biofuels and fossil fuels. Hence, lower crude oil prices imply larger support. At the same time, the incentive for providing subsidies for the production and use of fertilisers declines with lower energy prices. On the other hand, a stylized analysis of the fertiliser support under imperfect competition – which may be suspected for phosphorous and potash markets due to the relatively high regional concentration of mining reserves – shows that such conditions might significantly reduce the effectiveness of fertiliser subsidies in reducing input costs for farmers.

A number of caveats apply to the present analysis. Generally, economic model results depend on behavioural parameters and data that are subject to a certain degree of uncertainty. More importantly, the present analysis abstracts from a number of relevant developments in biofuel markets, including second-generation biofuels, biofuels from waste oil and other residues, and the variety of vegetable oils used as biodiesel feedstocks. On the fertiliser side, secondary nutrients and micronutrients are not considered in this study. Similarly, farmers' adjustments to changes in input prices are represented in a simplified manner, potentially underestimating their adaptation possibilities. This analysis makes a first attempt to better understand the implication of imperfect competition for policy effects, but does not assess the degree of market imperfections itself. More work will need to be done to better understand whether and to what degree some of these markets might actually be imperfect.

1. Background and objectives of the study

Policies play an important role in determining developments in the agricultural sectors of most OECD and many other countries. As shown by work undertaken by the OECD, agricultural policies and related transfers were responsible for almost one-fifth of all gross farm revenues across OECD member countries in 2012, down from more than one-third as observed in 1999. The variability in support levels across OECD countries has been, however, large. At the same time, several emerging economies are often found to show much lower support levels (OECD, 2013a).

Measuring transfers to agricultural producers has been a core activity for the OECD for a long time. The OECD's Producer Support Estimate (PSE) and related indicators allow developments in agricultural policies to be compared both across countries and over time in a consistent way. They are widely used for policy analysis and for facilitating policy reform at both national and multi-national levels.

Agricultural markets do not, however, exist in isolation from other parts of the economy. On the contrary, the agricultural sector forms part of a longer supply chain, with strong links to both upstream and downstream industries and markets. Consequently, farming and sales of agricultural products strongly depend on the supply of relevant production inputs, such as fertilisers, agro-chemicals and machinery, as well as on the demand for agricultural produce from other industries, including the food processing sector and non-food uses. Policies related to these upstream and downstream markets therefore have the potential to impact on agricultural production, demand, prices and incomes, and understanding the potential implications of policies on farm revenues requires looking beyond agricultural policies only.

For this study, two key sectors were selected to illustrate the implications that policies applied at different points along the agricultural supply chain might have for agricultural markets and farm incomes. First, fertilisers represent one of the main inputs into crop production. Augmented by higher energy prices in the second half of the past decade, the cost of fertilisers represents a significant share in agricultural production costs around the world. Several emerging economies have identified greater use of commercial fertilisers as an important means to improving their domestic agricultural production base and increasing farmers' incomes.

Within the group of fertilisers providing macro-nutrients to crops, a fundamental distinction needs to be made between nitrogen on the one hand, and phosphorus and potassium on the other. The production of nitric fertilisers is a highly energy intensive process, and production costs strongly depend on energy prices. Consequently, the production of nitrogen-based fertilisers — while undertaken in most countries — is generally cheaper in countries with large supplies of energy products and hence low energy prices.[1] As shown below, policies often aim at reducing energy costs in the production of nitric fertilisers, with the objective to provide the fertiliser 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 fertilisers is more demanding – and hence more costly – for phosphate than for

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[1] Note that some energy exporters, such as, for example, Russia and several Middle-East countries, apply lower energy prices for domestic users – including fertiliser producers – than for exports. In that case the prices paid by fertiliser producers may not represent the full opportunity costs for the use of natural gas.

potassium.[2] For these two fertiliser groups, transportation and handling represent important cost elements, and several countries provide subsidies to reduce costs related to these activities.

Second, the production of biofuels from agricultural commodities has become increasingly important in the last two decades in North America and Europe, while the use of sugar cane for the production of fuel ethanol in Brazil became significant already during the 1970s. Policies have supported the production and use of biofuels for various reasons, including, but not limited to, the aim to reduce the use of imported fossil fuels and the emission of related green-house gases (GHGs). Biofuels — notably ethanol (a substitute for gasoline in spark-ignition engines) from sugar crops or cereal starch, and biodiesel (a substitute for petroleum diesel in compression-ignition engines) from vegetable oils, animal fats, or used cooking oil — can be used in most existing motor vehicles, within certain ranges limited mainly by technical constraints in the combustion engines. Various “drop-in fuels”, such as synthetic paraffinic kerosene (a substitute for jet fuel), which do not require blending with fossil fuels, are currently under development. Given the large size of fossil-fuel markets relative to the market for agricultural commodities, implications for agricultural markets are potentially significant (OECD, 2008).

Complementing existing knowledge and on-going work on agricultural policies, this study aims to improve the understanding of support policies applied to upstream and downstream sectors by analysing their potential implications for agricultural markets and incomes. This analysis is undertaken in a forward-looking manner: alternative policy settings are compared with a baseline scenario that assumes current trends and policies to be continued to 2025. Both baseline and counterfactual scenarios are simulated using the computable general-equilibrium model MAGNET which, as described in more detail below, has been adjusted to represent the specificities of fertiliser, biofuel and agricultural markets and the relationships between them. As policy implications may depend on other, external factors, the analysis is complemented by sensitivity analyses looking more closely at a fundamental factor affecting both fertiliser and biofuel markets: as both the use of biofuels for transport and the production of fertilisers strongly depend on energy price levels, changes in future prices for crude oil, natural gas and other energy carriers are likely to affect the impact fertiliser and biofuel policies have on markets. A sensitivity analysis relative to energy prices is therefore important to fully understand these policy implications Second, as phosphorus and particularly potassium fertilisers are essentially mined products, and because natural reserves of these resources is unevenly distributed across countries and companies, the question of imperfect competition in fertiliser markets is of particular interest. This report cannot attempt to analyse the oligopolistic behaviour itself that is claimed to be present in fertiliser markets. Instead, it shows by stylized sensitivity analyses the potential implications such behaviour might have on the effects of fertiliser support policies.

This report is structured as follows. Section 2 provides an overview on support policies in the fertiliser and biofuel sectors in OECD countries and key emerging economies. This overview is based mainly on the OECD Fertiliser and Biofuel Policy Database (OECD, 2013b), which brings together information from governments and other sources. Section 3 presents the approach taken to analyse the implications of these

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[2] Agricultural-grade phosphate fertilisers often contain impurities such as fluorides, cadmium and uranium, depending on the source of the phosphate and the production process. These potentially harmful impurities can be reduced or removed but at a significant cost.

policies. This presentation focuses on the quantitative tool used and the different scenarios simulated. Section 4 presents the results of the analysis. This discussion will remain as much as possible non-technical. Section 5 concludes by summarizing the findings.

2. Key fertiliser and biofuel support policies

Support policies for fertilisers

Macronutrients, i.e. nitrogen (N), phosphorus (P) and potassium (K), are a key input to agricultural crop production. However, the intensity of fertiliser differs widely across countries (FAOSTAT, 2013). At 30% of global use of fertiliser nutrients (NPK only), China is the largest user of fertilisers – and with close to 300kg and more than 100kg, it also has the highest use of N and P fertilisers per hectare of cropland, respectively (based on FAOSTAT data on fertiliser use and cropland). At the other end of the spectrum, N use per hectare is below 25kg in a number of countries. Notably in a range of developing countries of sub-Saharan Africa, fertiliser use is known to be very low (Morris et al., 2007). The five largest fertiliser consumers (China, India, UNITED STATES, EU27, and Brazil) together account for 72% of the world’s total fertiliser consumption. On average, global fertiliser consumption can be split into 59% N, 24% P and 17% K. However, these shares differ significantly between regions, e.g. Brazilian fertiliser consumption is 26% N, 35% P and 39% K.

Different concerns drive fertiliser policies in OECD and non-OECD countries. Environmental and consumer safety concerns prevail in the majority of OECD countries. Intensification of fertiliser use is widely seen by society as an undesirable trend due to its perceived high environmental and consumer costs. Policies towards fertilisers in OECD countries are therefore focused on the control of environmental and human health impacts of fertiliser manufacturing and use and are based on regulatory instruments, rather than on economic (support) instruments.

By contrast, support of fertiliser use remains central to agricultural growth strategies in non-OECD countries, although in some of these countries concerns about fertiliser misuse or overuse are already voiced. An increase in fertiliser 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 fertiliser manufacturing was part of these countries’ industrial strategies. In the Russian Federation 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 fertiliser consumption, which included considerable interventions in fertiliser 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, the Russian Federation, and Ukraine have eliminated previous state regulation. However, these countries continue to support fertiliser use through direct subsidies to producers or through preferential lending. Most recently, the 2008 financial crisis prompted *ad hoc* interventions in fertiliser pricing in the Russian Federation and Ukraine.[3]

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[3] “Dual pricing” – the availability of energy to domestic users at prices well below those charged for exported energy – represents an important form of support to fertiliser (particularly nitrogen)

Fertiliser policies can be targeted at different levels, from the input use in the production of fertilisers to the end use of fertilisers. Both types of policies tend to lower the user costs of fertiliser to enhance the use of fertiliser and in the long term to increase yields and output of agricultural crop production. This policy will lead to some combination of increased domestic production of fertiliser and increased imports of different fertilisers. Input subsidy programmes have been discussed also in terms of a contribution to an increased national food security (Dorward, 2009).

If the policy measure is targeted at the domestic production of fertilisers, often prices of imported fertilisers are also controlled via price ceilings or import subsidies. Many countries listed in the OECD database on fertiliser and biofuel also apply import tariffs on different categories of fertilisers.

The OECD Fertiliser Database (OECD, 2013b) provides information on fertiliser support policies relating to nitrogen, phosphate and potassium fertilisers for 33 countries plus the European Union. It focuses on policies supporting the production or use of fertilisers, but excludes regulatory measures related to the abovementioned environmental or consumer safety concerns. Consequently, for 15 of these the database shows no policy measure at all for fertilisers. Eleven countries indicate bound or applied import tariffs, two countries grant value-added tax concessions on fertilisers, and six countries indicate multiple policy instruments in the area of fertilisers.

Out of the 11 countries, four countries apply import tariffs at the zero level. The applied import tariffs on fertilisers for 2007 are rather low and are listed in Table 1. On the other hand, OECD (2013b) shows that several countries applied export duties in specific years, including Argentina (2010-11, with an *ad valorem* equivalent of 5%), the Russian Federation (until 2009 with rates varying across years and types of fertilisers), and China (20% on phosphate fertilisers from February 2008; this was extended to a 100% export duty on all fertilisers and related material exports from April 2008, and further raised to a 150% export duty in September 2008, before being discontinued after January 2009). Finally, Indonesia has banned urea exports since 2006.

Both Portugal and Spain grant VAT concessions on fertiliser purchases: in Portugal this concession is between 4% and 5% instead of 15% to 21%, depending on the region, and in Spain it is 10% instead of 21%.[4]

Apart from import tariffs and VAT concessions, the OECD database on fertiliser covers data on payments for fertiliser use for the following countries: China, Indonesia, Poland, the Russian Federation, and Ukraine. The information on policies related to fertilisers is given in total payments at national currency. In China the centrally funded comprehensive subsidy on agricultural inputs was introduced in 2006 and by 2008 had become the most important single budgetary transfer supporting agriculture. While the objective of this subsidy is to compensate grain producers for an increase in prices of agricultural inputs such as fertilisers, diesel fuel, pesticides and plastic films, it is implemented as a payment per unit of land, not necessarily sown to grains. This makes it a direct payment supporting farmers' incomes. Budgetary transfers for this programme

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producers as well, but while embedded in the GTAP database used, it is not discussed in greater detail in this report as it is not specific to the fertiliser sector.

[4] Both countries have increased their concessional and standard TVA rates somewhat in recent years.

more than doubled in 2008 and have increased each year since to reach CNY 107.8 billion (USD 17.1 billion) by 2012.

In Poland subsidies on fertilisers are granted for liming forests to reduce the impact of acid rain in forests. Payments have fluctuated between USD 0.1 million in 2009 and USD 1.5 million in 2005.[5] Input subsidies granted to Ukrainian farmers in 2007 were phased out in the following year and therefore also not covered in our analysis. The Russian government spent around USD 148 million on fertiliser input subsidies in 2007.

Compensation to Indian fertiliser producers covers the reduced revenues on fertilisers following the regulated prices for both domestically produced and imported fertilisers. These compensatory payments to fertiliser producers were equal to USD 8 billion – more than 0.8% of the country’s GDP in 2007. The Indonesian government spent around USD 690 million or 0.2% of its GDP on fertiliser output subsidies in that year.

Table 1. Tariffs on fertiliser imports, *ad valorem*, in per cent, 2007

	Nitrogen	Phosphorous	Potassium
Argentina	1.4	2.0	0.8
Brazil	0.8	1.0	1.0
Chile	6.0	6.0	6.0
China	9.1	4.0	3.0
EU	6.1	2.4	0.0
Indonesia	10.3	12.5	10.0
Israel	4.4	8.0	4.0
Russia	10.0	10.0	10.0
Switzerland[1]	1.21 CHF/100kg	0.0	0.0
Turkey	6.1	2.4	0.0
Ukraine	4.7	5.0	4.2

Note: 1: specific-rate tariff.

Source: OECD (2013b).

Support policies for biofuels

Ethanol and biodiesel based on agricultural crops are the most commonly produced biofuels. Among the two, ethanol is far more important than biodiesel. Whereas the production of ethanol reached over 97 billion litres in 2012, that of biodiesel was roughly 26 billion litres. Ethanol production is led by the United States (45 bn litres) and Brazil (24 bn litres), with China, the European Union, Canada and India also producing significant quantities.[6] Biodiesel production is strongly concentrated in the European Union (11 bn litres in 2012), while the United States, Argentina and Brazil also produced more than 2 bn litres each.

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[5] Due to the fact that this policy is not targeted to agricultural production this policy is not considered in the analysis of this study.

[6] Note: some of these numbers include production of ethyl alcohol for beverages and other non-fuel uses.

Ethanol is made mainly from starch-yielding grains, in particular maize (United States), and sugar cane (Brazil) and its derivative molasses (India). Biodiesel is today produced mainly from virgin vegetable oils, but can be made from any lipid source, such as used cooking oil and tallow.[7] Feedstock quantities used for the production of biofuels are significant: 11% of global coarse grains produced, 13% of vegetable oils and 16% of sugar cane were used in the production of biofuels in 2012 (OECD-FAO, 2013). Production of grain-based ethanol at the same time yields distiller's dried grains and solubles (DDGS) as a high-protein by-product that can be used as an animal feed. Oilseed meals, a by-product of oilseed-based vegetable oils, is also used as a protein-rich animal feed.

Domestic support measures

Biofuel support polices concerning domestic markets can be clustered into three different categories: payments, tax rebates or exemptions, and mandates or targets.[8] Payments increase the economic incentives to produce, consume or store biofuels. Tax rebates or exemptions are meant to stimulate consumption of biofuels. Both categories typically do not specify a goal measured in quantitative terms.[9] Mandates in contrast are a legal means by which, for example, the petroleum industry is forced to blend a certain share or volume of biofuels into fuels of fossil origin. Targets are less binding than mandates because they are voluntary and are not effective at the individual agent level.

A fourth category of policies relevant to biofuels comprises sustainability criteria which are applied for biofuels in an increasing number of countries. These criteria modify the effects of support policies as they generally require biofuels to comply with certain, mainly but not only environmental, conditions to qualify for other support measures or to count towards biofuel mandates (see also Bahar et al., 2013).

Across countries covered by the OECD Database on Biofuel Policies (OECD, 2013b), payments (including tax measures) to **consumption** are the most widely applied measure; thirty out of thirty-five countries included in the OECD database on biofuel and fertiliser policies promote the consumption of biofuels through such measures (Table 2). In most cases, these are excise tax exemptions which lower the price paid by users of biofuels. In some countries, e.g. Austria, Belgium and Estonia, the excise tax exemption is 100%. In others, only part of the excise tax is waived. Examples for countries with partial tax reductions are France, Italy and Poland. Among these, there are countries which grant the tax relief only to an agreed amount of biofuel production (for example France and Italy). Bahar et al. (2013) suggest that there is a trend to move away from tax exemptions to volumetric subsidies or consumption mandates. OECD-FAO (2013) assumes for example that the ratio exempted tax/fossil fuel tax in the EU-27 and will be by about 10 and 30 percentage points lower from 2013 and onwards compared to the level it was in 2007 for ethanol and biodiesel respectively. For Canada this ratio is assumed to reduce by about 30 and 15 percentage points for ethanol and biodiesel respectively (OECD-FAO, 2013). To

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[7] Focussing on first-generation biofuels from grains, sugar crops and vegetable oils, neither biodiesel from these secondary sources, nor second-generation biofuels from cellulose and other biomass are considered in the analysis of this study.

[8] Another way of supporting the production and use of biofuels is through public procurement, e.g. for military vehicles. Such policies are not considered in the present study.

[9] In some cases, however, these measures, notably tax credits or exemptions, apply up to a specific volume produced or consumed, or only for additional volumes above a mandated level.

note, US ethanol tax incentives for ethanol and biodiesel (such as the volumetric ethanol excise tax credit, the small ethanol producer credit, the small agri-biodiesel producer credit, the renewable diesel tax credit) expired on December 2011, whereas credits for the production of cellulosic biofuels were set to expire by the end of 2012 (Yacobucci, 2012). The biodiesel tax credit, which also expired in December 2011, became renewed to run through 2013. No further renewal is assumed in the economic analysis for this study, although it is possible that it is extended again.

According to Bahar et al. (2013), Argentina provides for concessions on hydrocarbon and excise taxes for ethanol and biodiesel worth 39% and 40% of the gasoline and diesel tax rates, respectively. Support to biofuels in Argentina is regulated in Law No. 26.093. According to Argentine authorities, this law is currently not in force, however.

Payments or subsidies related to **output** are granted in Australia and in Canada. In Australia, there are two programmes promoting production (output) of biofuels, the "Ethanol Production Grants Program" and the "Energy Grants (Cleaner Fuels) Scheme". The former provides full excise reimbursement to ethanol producers for ethanol produced and supplied for transport use in Australia from locally derived feedstocks (Australian Government, 2012a). This programme is planned to continue until June 2021 and to be revised afterwards (Australian Government, 2012a). The latter is a similar scheme, but applies to the production and also importation of biodiesel and has been extended indefinately from July 2011 (Australian Government, 2012b). In Canada output based payments were introduced in 2008 and replaced tax exemptions at federal level and at some provinces. The Canadian federal government provides financial incentives for the period 2008-2017 for the amount of litres produced in Canada under its established the ecoENERGY for Biofuels Program (Natural Resources Canada, 2012). In addition, there are programmes at provincial level in Alberta, Manitoba, Ontario, Quebec and Saskatchewan, the duration of which varies per province (Laan et al., 2009 and OECD, 2013b).

In Canada a number of programmes promoted biofuel production through support to capital, e.g. by subsidised interest rates or grants for the construction of ethanol refineries or other biofuel facilities. At federal level for example these are the National Biomass Ethanol Programme, which accepted applications until 2006, the Ethanol Expansion Programme, which ran between 2003 and 2006, the ecoAgriculture Biofuels Capital Initiative, which lasted from 2007 to 2012 and the Biofuels Opportunities for Producers Initiative, which provided grants to biofuel producers between 2006 and 2008 (Laan et al., 2009 and OECD, 2013b). Provincial programmes ran in Alberta, British Columbia, Manitoba, Ontario, Quebec and Saskatchewan and like the federal programmes they provided capital grants only for a limited number of years (Laan et al., 2009 and OECD, 2013b). There are also specific measures supporting the development of second-generation and waste-based biofuels. For instance, the Alberta Bioenergy Producer Credit Programme provides aid to second-generation ethanol producers since 2007, but was discontinued in 2013. Sustainable Development Technology Canada – Next Generation Biofuels Fund, funded by the Government of Canada, provides financial support to establish first-of-kind commercial scale biofuel demonstration facilities.

In the United States, specific tax credits were provided for biodiesel produced from previously used agricultural products between 2005 and 2007.

Aid to **storage and handling** was granted in Australia and in the United States. In Australia, the Ethanol Distribution Programme supported from 2006 to 2009 gas station in offsetting the cost to install the means to provide ethanol blended petrol (Quirke et al., 2008). In the United States, support to the storage of biomass that is to be converted into biofuels is granted through the Biomass Crop Assistance Programme (Stubbs, 2011). The programme was established at 2008 and was scheduled to terminate by the end of the fiscal year 2012 (Yacobucci, 2012).

Biofuel mandates are applied in 23 of the countries included in the OECD database (2013b). Details on biofuel mandates are given in Table 3. For the European countries, these are defined as a share of biofuels in total transport fuel (European Parliament and Council, 2009). Nevertheless, some individual member countries report separate shares for biodiesel and ethanol. In Brazil, ethanol plays the predominant role, and the incorporation mandate defined as a percentage share of ethanol that must be blended into gasoline (so-called gasohol) used for motor vehicles (Ministério da Agricultura Pecuária e Abastecimento 2011). In Brazil and Sweden in particular, significant amounts of ethanol are used in high-level blends by owners of flex-fuel vehicles (FFVs) – vehicles that can use ethanol and gasohol in flexible shares. In Canada, the mandate relates to the percentage share of ethanol and biodiesel in the total supply of diesel or gasoline (Canada, 2011).

Several states and union territories in India have established mandatory blending requirements for ethanol. However, in the recent past these mandates have not been filled.

Indonesia has imposed mandatory blending requirement both for ethanol and biodiesel, defined as percentage shares in total transportation fuel. In Indonesia, biofuel blending is not enforced at the retail level, but is negotiated between the Indonesian government and Petramina, the state-owned oil company. Any cost difference between biofuels and fossil fuels is to be covered by the Indonesian government, but depending on the magnitude of this cost difference compensation by the government may be incomplete. In consequence, actual blending levels in reality are often below the mandate. In practical terms, the Indonesian biofuel policy therefore lies somewhere in between a mandate and a target. Dillon et al. (2008) explain that Petramina was required to sell biofuels at the same price as fossil fuels and had to cover the difference when producing biofuels cost more than fossil fuels. Petramina was faced hence with losses and reacted with lowering the biofuel content of its blends. Because Petramina is a state-owned company, these losses can be thought as a government subsidy.

Apart from tax incentives, Argentina’s Biofuel Promotion Regime, as regulated by Law No. 26.093, also provides for blending mandates for ethanol and biodiesel. Currently, these mandates are set at between 5% and 10% for ethanol and at 7% for biodiesel. Both are expected to reach 10% in the coming years (Bahar et al., 2013; FAS, 2013).

Table 2. Main categories of domestic support in countries covered by the OECD Database

	Payments (including tax measures)			**Mandates**	**Targets**
	Biofuel Output	Handling or Storage	Consumption		
AUS	x	x	x	x	
AUT			x	x	
BEL			x	x	
BGR			x	x	
BRA				x	
CAN	x		x	x	
CHE			x		
CYP			x		
CZE			x	x	
DNK			x	x	
ESP			x		
EST			x		
EU				x	
FIN			x	x	
FRA			x		
GBR			x	x	
GER			x	x	
GRC			x	x	
HUN			x	x	
IDN				(x)	(x)
IND				x	
IRL			x		
ITA			x	x	
LTU			x		
LUX			x		
LVA			x		
MLT			x		
NLD			x	x	
POL			x	x	
POR			x	x	
ROU			x	x	
SVK			x	x	
SVN			x	x	
SWE			x		
USA	x1)	x		x	
TOTAL	4	2	30	23	1

Note: 1) Measure expired for conventional biofuels.

It should also be noted that the OECD Database has partial country coverage only and hence excludes biofuel support policies, including mandates, in other countries. In particular, this study additionally considers biofuel budgetary support in Argentina and China.

Source: OECD (2013b).

Table 3. Biofuel mandates in countries covered by the OECD Database

Country		Biofuel type	Unit	2007	2010	2012
Brazil		Ethanol	% (vol.)	24	24	20
		Biodiesel	% (vol.)	0	5	5
Canada		Ethanol	% (vol.)	0	5	5
		Biodiesel	% (vol.)	0	0	2
EU (27)	Austria	Biofuel	% (energy)	2.5	5.75	5.75
	Belgium	all biofuels	% (energy)	3.5	5.75	na
	Czech Republic	Biodiesel	% (vol.)	na	5.4	6
		Biogasoline	% (vol.)	na	3.9	4.1
	Denmark	Biofuel	% (energy)	na	0.75	5.75
	Finland	Biofuels	% (energy)	na	4	6
	Germany	Biodiesel	% (energy)	4.4	4.4	4.4
		Biogasoline	% (energy)	1.2	2.8	2.8
	Ireland	Biofuel	% (vol.)	na	4.166	4.166
	Italy	Biofuel	% (energy)	na	3.5	4.5
	Luxembourg	Biofuel	% (energy)	2	na	na
	Netherlands	Biofuel	% (energy)	2	4	-
	Poland	Biofuel	% (energy)	na	5.7	6.65
	Romania	Biogasoline	% (vol.)	na	na	na
	Romania	Biodiesel	% (vol.)	4	na	na
	Slovak Republic	Biofuel	% (energy)	2	5.75	na
	Slovenia	Ethanol	% (energy)	2	5	na
		Biodiesel	% (energy)	2	0	na
	Spain	Ethanol	% (energy)	na	2.5	4.1
		Biodiesel	% (energy)	na	2.5	7
	UK	Biofuel	% (vol.)	na	3.5	4.5
India		Biofuel	% (vol.)	0	5	5
Indonesia		Ethanol	% (vol.)	na	2.5	2.5
		Biodiesel	% (vol.)	na	3	3
USA		All renewable fuel	% (vol.)	4.02	0	0
		Cellulosic biofuel		0	0.004	0.006
		Biomass-based diesel		0	1.1	0.91
		Advanced biofuel		0	0.61	1.21
		Renewable fuel		0	8.25	9.23

Source: OECD (2013b). Not included are mandates at state or provincial levels. It should also be noted that the OECD Database has partial country coverage only and hence excludes biofuel support policies, including mandates, in other countries. More specifically this study considers biofuel mandates in Argentina and Malaysia.

Malaysia is not providing any direct subsidy for the production or use of biofuels (biodiesel in particular) but has introduced a mandatory blending requirement of 5% in the central region only. This is planned to increase up to 10% and to cover the entire country by June 2014 (Bahar et al., 2013; Lopez and Laan, 2008). In the United States, the quantities of different categories of biofuels blended into fossil fuels[10] have been defined in volumetric terms (Schnepf and Yacobucci, 2013). The US system implies that the share of biofuels in total fuel may grow or shrink over time, depending on the total use of fuels.

China is promoting its biofuels industry through a series of supportive measures, but continues to have problems with large-scale biofuel production. The new goal is to use 5 million tons of ethanol fuel during the 12th Five-Year period covering 2011 to 2015. This represents almost twice the target set for the previous period (2006-2010) (Renewable Energy World, 2012).

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[10] Total renewable fuels, advanced biofuels, cellulosic and agricultural waste-based biofuel and biodiesel.

In addition, several countries have initiated research programmes which accumulated to more than USD 1.4 billion between 2005 and 2012. Most of the research programmes have been initiated in the United States (60% of total funding) and in the European Union at both EU level as well as at the level of different EU Member States (30%). Since 2005, funding of biofuel-related research grew from about USD 5.3million to USD 326 million in 2010, but fell slightly thereafter.

Trade measures

Several countries apply tariffs to imports of biofuels. As shown in Table 4, both ethanol and biodiesel trade are subject to import tariffs. Canada, the EU and Indonesia impose higher import tariffs on ethanol than on biodiesel, whereas the opposite is true for the United States. In Australia and India, both biofuels are subject to the same import tariff rates.

On the export side, Argentina applied an export tax for biodiesel of 18.3% in 2012, which is expected to increase to 24% by 2022 (OECD-FAO, 2013).

Table 4. Import Measures for biofuels in countries covered by the OECD Database, applied MFN, 2012 or latest year available

Country	Ethanol		Biodiesel	
Australia	5.00%	Denatured or undenatured alcohol	5.00%	HS 382.90.90: Biodiesel
Canada	4.92 CAD/hl	HS 2207.20.12		
	12.28 CAD/hl	HS 2207.10: Undenatured alcohol, alcohol content > 80%; applies to ethanol content only		
	4.92 CAD/hl	HS 2207.20: Denatured alcohol; applies to ethanol content only		
EU	19.2 EUR/hl	HS 2207.10.00: Undenatured alcohol, alcohol content > 80%	6.50%	HS 3824.90.97
	10.2 EUR/hl	HS 2207.20.00: Denatured alcohol		
India	28.64%	Ethanol	28.64%	Biodiesel
Indonesia	30.00%	Denatured or undenatured alcohol	5.00%	HS 3824.90.91.00
United States	2.50%	HS 2207.10.60: Undenatured alcohol, alcohol content > 80%, for non-beverage purposes	4.60%	HS 3826.00, Biodiesel, B>30 to B99
	1.90%	HS 2207.20.00: Denatured alcohol	6.50%	HS 3826.00, Biodiesel, B100

Source: OECD (2013b).

3. Approach for analysing the potential implications of fertiliser and biofuel policies on agriculture and farm incomes

This section describes the methodological approach of the present analysis. It focuses on two key elements. The first section discusses the economic model used for the analysis, highlighting in particular the elements of the model most relevant for modelling the analysed stages in the supply chain, i.e. the markets for fertilisers, agricultural products and biofuels, as well as the representation of fertiliser and biofuel supply policies. The second section outlines the reference and various counterfactual scenarios calculated, presents some of the key assumptions and discusses the way the implications of fertiliser and biofuel policies for markets and agricultural incomes are assessed.

MAGNET: What does it make suitable for this analysis?

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 fertilisers, 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 fertiliser 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 set out in Eickhout et al. (2009).
- **Land allocation**: MAGNET allows for the substitutability of land to vary across (but not within) different types of land use. Land heterogeneity is introduced via a nested constant elasticity of transformation (CET) function. The CET elasticities are based on the OECD’s Policy Evaluation model (PEM) (OECD, 2003; Huang et al., 2004).
- **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 fertilisers (first level) and substitution between various fertilisers (second level). Furthermore, we use a one-level nested CES structure to account for substitution among ethanol feedstocks. The blending sector and the fertiliser 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.
- **Biofuels**: MAGNET includes first-generation ethanol and biodiesel as separate sectors. Biofuel consumption data for 2007 are taken from the *World Energy Outlook* (IEA, 2011). The model assumes that ethanol is produced from grains (wheat, coarse grains) and sugar beet or sugarcane, whereas biodiesel is assumed to be made entirely from crude vegetable oil. Furthermore, the model includes by-products of the biofuel processing activities, such as oilcakes (by-product of crushing oilseeds) and dried distillers grains with solubles (DDGS) (a by-product of producing ethanol from grains). These by-products are used as intermediate inputs in livestock production.
- **Biofuel policies**: MAGNET captures changes in biofuel mandates by targeting biofuel shares in transport. Obligatory blending is modelled by introducing a biofuel share which can be targeted to implement the mandates. Furthermore, a subsidy on biofuel use is introduced to achieve the targeted blending rate. In this study, the subsidy on biofuel use is made budget-neutral by an offsetting tax related to total fuel consumption. The model assumes that the petroleum sector blends fossil gasoline and diesel with ethanol and biodiesel via a CES function. The nested CES structure implies that biofuel demand is determined by the relative prices of crude oil versus ethanol and biodiesel, inclusive of taxes and subsidies. In addition, and as part of the standard GTAP approach, other budgetary support to the production and use of biofuels are considered as well.
- **Fertilisers**: MAGNET is extended to explicitly account for the three macronutrients: nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O). Data on fertiliser use per crop and per country for 2007 are taken from Heffer (2009).[11] Bilateral trade data for fertiliser products, extracted from the BACI database, are converted into the three macronutrients using conversion factors provided by IFA (2013a) (Figure A.2). Assuming that the three nutrients are used as intermediate inputs in the crop-producing sectors identified in Heffer (2009), we calculate the implied production volume. The three macronutrients enter MAGNET as separate sectors, which implies that the original chemical sector in the GTAP database is split into four sectors (nitrogen, phosphorus, potassium and rest of chemicals). The output value of fertilisers is derived using the following fob prices as reference prices: Urea (HS 31102.10) for nitrogen, DAP (HS 3105.30) for phosphorus, and MOP (HS 3104.20) for potassium (Figure A.3). Bilateral tariff data obtained from the 2007 MacMap database for Urea, DAP and MOP, serve as reference bilateral tariffs for nitrogen, phosphorus and potassium, respectively. The production technology for the three fertiliser sectors is derived from IFA (2013b). There are regional differences in the production technology of nitrogen in particular which are due to regional

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[11] Countries that are not covered explicitly in Heffer (2009) are assumed to follow the same proportion of fertiliser use as the Rest of World aggregate.

> deviations in natural gas prices. The rest of the chemicals sector is then calculated residually. Initial tax rates on primary factors and on firms' domestic and imported purchases of the three macronutrients are based primarily on OECD (2013b) where given and assumed to be consistent with the original GTAP chemical sector for countries not covered in this database. Data adjustments in MAGNET are implemented in the model's underlying Social Accounting Matrix (SAM). For the rest of the chemicals sector, taxes and subsidies are adjusted accordingly so that the SAM remains balanced. The model assumes that fertilisers can substitute for land in crop production, thereby accounting for extensification vs. intensification of agricultural production.[12]

The derived output values for 2007 suggest that China is the biggest nutrient producer worldwide, followed by India, the United States and Brazil. Chinese trade in nutrients appears to be relatively low compared with its consumption and production, suggesting that the country is self-sufficient and its production serves mainly the domestic market.

Aggregation and data

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 fertiliser 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), by-products used as compound feed components (DDGS, oilcakes), biofuels (ethanol and biodiesel), the three fertiliser macronutrients (nitrogen, phosphorous and potassium) and the energy sectors (crude oil, natural gas and coal). The regional disaggregation separates countries key to the biofuel and fertiliser markets such as Argentina, Brazil, Canada, China, EU27, India, Indonesia, Morocco, the Russian Federation, and the United States, from geographical aggregates.

Limitations of the modelling approach

Notwithstanding the power of CGE models like MAGNET and the various adjustments outlined above, the limitations of such models in reflecting some of the detailed dynamics of agricultural fertiliser and biofuel systems should be born in mind when interpreting the model results (Woltjer et al. 2011). At a general level, models are simplified representations of economic relationships that, by definition, cannot cover all details that might influence actual outcomes of policy changes. In addition, due to the Armington trade specification that relates relative changes in trade shares to relative changes of price ratios, this type of models tends to be conservative with respect to the structure of international trade: small trade flows generally remain small even in trade liberalization scenarios, possibly underestimating trade and production effects. However, trade policies in the fertiliser and biofuel sectors covered in this analysis, and hence trade policy changes, are limited, thus reducing the importance of this potential bias.

The analysis discussed here is done in a comparative-static manner for a medium- to long-term time horizon. In consequence, results relate to market and income effects after relevant adjustments with the sector (and elsewhere) have been made. Short-term

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[12] The substitution elasticity is set at 1.25 and is taken over from GTAP-AGR.

disruptions that could derive from sudden changes in policy regimes are therefore not shown by the numbers discussed below.

Another limitation relates to the representation of different biofuels. Focusing on first-generation biofuels from crops, this analysis abstracts from second-generation biofuels: while different technologies are available today to convert other biomass to liquid fuels, these remain too costly and economically unviable. In consequence, quantities have remained well below plans, and any assumption on future paths on technological change, economic viability and output quantities remain highly uncertain. Competitive second-generation biofuels could reduce the role of first generation biofuels, thus potentially limiting the impact of related policies on the agricultural sector and land use. Another development not reflected in this analysis relates to biodiesel from waste oil and other residues, a group of biofuels that indeed plays a role in the EU and elsewhere. To the degree such biofuels replace biofuels from crops the results shown in this study may overestimate actual policy impacts – but to date these biofuels represent a small share of the total.

With regard to first generation biofuels it is important to note that the various vegetable oils (e.g. palm, soybean, sunflower or rapeseed oil) used in the production of biodiesel are not differentiated in this analysis. In consequence, the impacts shown here on land use and agricultural production abstract from the potential substitution among these input commodities which might alter the policy effects. In terms of biofuel policies, the increasing importance of sustainability criteria linked to support measures in many countries is not accounted for in the analysis. These tend to limit the choice of biofuels and their feedstock commodities that qualify for support (or for counting towards mandates), and may therefore alter the impact the support policies have on agricultural markets and incomes. An assessment of the direction and potential magnitude of these modifying effects is, however, beyond the scope of this analysis.

On the fertiliser side, the use of a CES function for the substitution between fertiliser and land is a simplification of the complex relation between land, fertiliser and management techniques (rotations, crop selection and crop management). In the event of large fertiliser policy changes this might underestimate the farmers' adaptation possibilities and hence might overestimate the impact of the decline in fertiliser use on production levels and, therefore, on prices. It should also be noted that data on fertiliser prices and use – notably at a more disaggregated level – are subject to considerable uncertainty, potentially further reducing the precision of the results discussed in this analysis. Finally, as mentioned before, the model assumes perfect competition in all markets. Potential implications of possibly imperfect competition in some fertiliser markets are looked at specifically in this report, showing that in the presence of market imperfections the implications of support policies may differ from those shown by the model results.

Counterfactual scenarios: Choice and key underlying assumptions

In order to address the questions presented in the introduction, the world economy is simulated from 2007 to 2025 both with and without fertiliser and biofuel policies. The simulations are presented and discussed in the following sections.

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 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 fertiliser and biofuel sectors.

Estimates of real GDP and population growth for the period 2007-2025 are taken from OECD-FAO (2013)[13] (Table A.4 in the Annex). 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 the Russian Federation 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). Values are given in Table A.6. Sectoral "factor embodied" technical change is calculated residually in a pre-simulation in order to replicate the given GDP growth path given endowment growth rates (Robinson et al. (2014) and Annex 1).

World crude-oil prices are assumed to develop as reported in OECD-FAO (2013)[14] and are assumed to reach USD 152 per barrel in 2025, whereas 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 (2013). Figure 1 shows historic and expected prices through time. Prices are assumed to reach USD 6 per million British thermal units (mm Btu; USD 5.8 per GJ) and USD 102 per tonne of coal equivalent (USD 3.5 per GJ) by 2025 respectively.[15,16]

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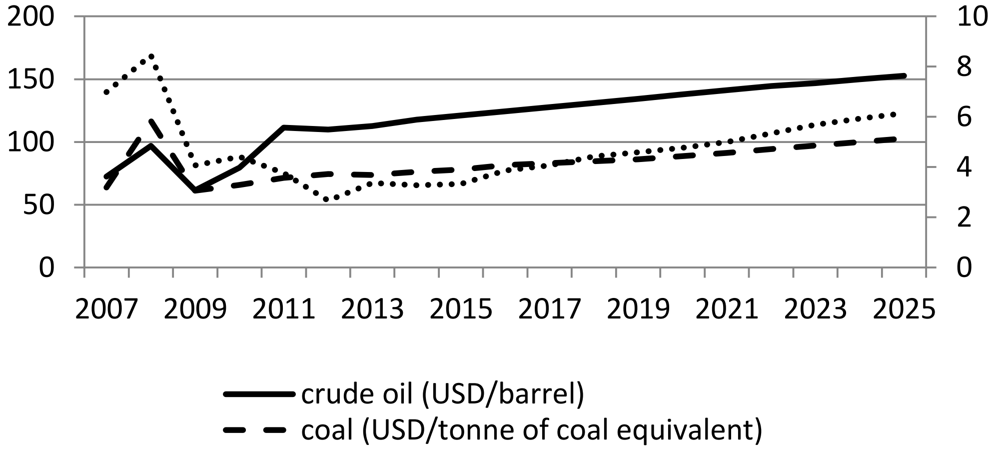
[13] OECD-FAO (2013) projects up to 2022. For the years 2023-2025, we extrapolate the trends of period 2017-2022.

[14] Crude oil prices for the period 2023-2025 are extrapolated and follow the trends of the period 2017-2022.

[15] As noted above, dual pricing results in lower energy prices paid by domestic consumers including fertiliser producers in several energy exporting countries. This is embedded in the reference scenario but not specifically looked at in the policy shocks.

[16] This study abstracts from the fact that natural gas markets have developed differently across world regions. This has been reinforced by the exploitation of shale gas notably in North America. As a consequence, gas prices e.g. on US, European and Japanese markets have developed quite differently in recent years. The present study makes no attempt to analyse the implications of these developments, but assumes one natural gas price for all markets.

Figure 1. Nominal energy prices in reference scenario, 2007-2025



Notes: Crude oil prices refer to Brent crude oil, coal to US delivered coal and natural gas to prices at Henry Hub; natural gas prices are displayed in the secondary vertical axis. "mm Btu" are million British thermal units, with 1 mm Btu corresponding to 26.4 cubic meters of natural gas with an energy content of 40 MJ per cubic meters.

Sources: OECD-FAO (2013); US EIA (2013); World Bank (2013).

Policy assumptions regarding fertilisers

Subsidies to the production and use of fertilisers were transformed into ad-valorem subsidy rates using fertiliser cost information available from the MAGNET database. Where relevant and possible, these rates were calculated separately for nitrogen, phosphate and potassium fertilisers. In most cases, however, these rates are identical across the three macronutrients as fertiliser-specific information was unavailable. The resulting input subsidy equivalents for the main countries subsidising the use of fertilisers in agriculture are shown in Table 5.[17]

These figures indicate the relevance of fertiliser subsidies to agricultural production in the four countries. With an output subsidy covering more than two-thirds of fertiliser costs, fertiliser support is particularly relevant for Indonesian agriculture. In the case of India, a fertiliser 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 fertiliser costs are covered by governmental intervention.

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[17] 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 fertiliser policies.

Table 5. Fertiliser 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: Calculated from OECD (2013b).

As described above, fertiliser-related support in China is provided as a *comprehensive subsidy on agricultural inputs*. Having an important motivation in the role of fertilisers 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 fertiliser use. The amount granted is equivalent to an *ad valorem* subsidy of approximately 12.5% of the value of fertiliser and of land in production costs, respectively.

Developments in covered fertiliser 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 5 are assumed to remain constant throughout the reference scenario. The MAGNET database builds on 2007 as the reference year.

Policy assumptions regarding biofuels

The reference scenario mirrors the different biofuel support policies described in Section 2. On biofuel **mandates**, eight economies are assumed to enforce biofuel mandates between 2010 and 2025: Argentina, Brazil, Canada, the EU, India, Indonesia, Malaysia, and the United States. As shown in Table 6, these mandates have essentially been assumed to remain unchanged throughout the reference scenario. Note that for Indonesia, the mandate level has been reduced to reflect the uncertainty on the degree to which the mandate will be filled.

Brazil is assumed to maintain a relatively high mandated share of ethanol in its gasoline mix, while Canada is assumed to mandate relatively low biofuel shares. In the MAGNET model, biofuel mandates are defined as shares of biofuel in total transportation fuel in energy terms. Hence, weighted averages are calculated from the shares in fuel types shown in Table 6. The shares of the respective fuel type in the total transportation fuel use are used as weights in the aggregation.[18]

Budgetary biofuel support measures described in Section 2 are transformed into *ad valorem* subsidy rates for ethanol and biodiesel using cost information from the

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[18] As explained above, mandates are modelled by introducing a budget-neutral subsidy for biofuels, financed by a tax on total fuel consumption. This approach is taken for all countries listed in Table 6 with the exception of Indonesia. For Indonesia, as also suggested above, the subsidy is born by the government.

MAGNET database for the base year 2007. These rates are adjusted between 2007 and 2025 (end year of the simulation period) following the announced changes of policies. In detail, biofuel tax exemptions and output based payments are assumed to stimulate biofuel use in the blending mix with fossil fuels, with the latter affecting only domestically produced biofuels.[19] They enter hence MAGNET as subsidies to the intermediate demand for biofuels from the blending sector.[20] Measures such as support to capital in Canada and aid to storage and distribution in the United States were discontinued after 2013 and are therefore not considered in the reference scenario.

Table 6. Blending mandates (blending rate with corresponding petroleum products)

		2010	2020	2025
Argentina	Ethanol	10%	10%	10%
	Biodiesel	7%	10%	10%
Brazil*	Ethanol	25%	25%	25%
Canada*	Ethanol	5%	3%	3%
	Biodiesel	0%	2%	2%
EU**		3%	7%	7%
India*	Ethanol	0%	5%	5%
	Biodiesel	0%	8%	8%
Indonesia*	Biodiesel	3%	3%	3%
Malaysia***	Biodiesel	5%	10%	10%
United States*	Ethanol	5%	10%	11%
	Biodiesel	1%	1%	2%

* Share of biofuel in the respective fuel type, energy equivalent.

** Energy Share in transport fuel consumption. Note that the EU's Renewable Energy Directive calls for 10% of transport energy use to come from renewable sources. Based on the recent debate by the European Parliament, the European Council and the European Commission, and given the ambition for a significant share of the renewable transport energy to come from second-generation biofuels, waste biomass and renewable electricity (not covered by this report), the reference scenario for this analysis assumes 7% of transport fuels to come from first-generation biofuels by 2020.

*** Currently the Malaysian mandate is applied only in the central region. From 2014 and onwards it should cover the entire country.

Note: Mandates represented in this table refer to first-generation biofuels from agricultural crops only. Both the EU and the US have higher mandates in place, reflecting the ambition to use significant amounts of second-generation biofuels, not covered by the analysis in this report.

Source: Calculated from OECD (2013b), OECD-FAO (2013 and 2012); Bahar et al. (2013).

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[19] Note that according to Argentine authorities, Law No. 26.093 which regulates Argentina's biofuel promotion regime in general, and which in particular provides for tax incentives for domestic biofuel use, currently is not in force. The reference scenario to 2025 assumes that the law will be enforced in the future as it is legislated, and that tax concessions are as indicated in Bahar et al. (2013).

[20] The petroleum sector in MAGNET blends fossil fuels with biofuels. Doing so implies that final demand is specified for the blended commodity and fossil fuels and biofuels are consumed as intermediate inputs to the blended commodity. These subsidies are hereafter denoted as biofuel output subsidies.

Import tariffs for biofuels are considered in the model and are defined on a bilateral basis.[21] The tariff rates for biodiesel vary between 0.5% and 5.7%, the highest tariff rate being observed for imports of biodiesel from the US to the EU (Table 7).

Table 7. *Ad valorem* equivalent import tariffs for biodiesel in per cent

Exporter	Importer		
	Canada	EU	United States
Argentina	2.8%	0*	0.5%
EU	5.5%	0	0.5%
Indonesia	2.8%	0*	0.5%
Malaysia	2.8%	0	0.6%
United States	0	5.7%	0
Rest of Europe	0	0	0.5%

* In late 2013, the EU introduced anti-dumping duties on biodiesel imports from both Argentina and Indonesia, which, however, are not accounted for in the model analysis.

Source: MacMap HS6 2007.

For ethanol, tariff rates are generally higher than for biodiesel. The highest rate is observed for exports of ethanol from Brazil to the EU, but also for trade flows from Canada to the EU and from Brazil or the EU to the Rest-of-Asia aggregate (Table 8).

Table 8. *Ad valorem* equivalent import tariffs for ethanol in per cent

Exporter	Importer			
	Canada	EU	United States	Rest of Asia
Brazil	3.7%	24.6%	1.3%	10%
Canada	0	6.9%	0	0
EU	0	0	1%	7.5%

Source: MacMap HS6 2007

In this study, we assume that there are no export subsidies for biofuels but that there is an export tax for Argentinian biodiesel exports set at 24% by 2025 (OECD-FAO, 2013).

In 2007 prices for fossil fuels (gasoline and diesel) were below production costs for biofuels (ethanol and biodiesel, respectively) when accounting for the lower energy content in biofuels compared with their fossil substitutes. The difference between the production costs for ethanol and the gasoline prices are estimated at 4% for Brazil, 30% for both India and Indonesia, 40% for the United States and 50% for the EU. The production costs of biodiesel are almost 50% higher than fossil diesel prices in most countries. This suggests that the base year initial biofuel shares in total transport fuel use

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[21] Note that the requirement for modelling import tariffs on a bilateral basis makes using the tariff data available from the MacMap database preferable relative to using the data available from OECD (2013b), which contains aggregate average data.

are driven mainly by mandates and other biofuel support policies whereas Brazilian ethanol was relative competitive against fossil gasoline.

Approach of scenario analysis

Counterfactual scenarios

The main counterfactual scenario removes the effects of fertiliser and biofuel policies from the reference scenario. To identify the separate impacts of individual fertiliser and biofuel policies, the total scenario impact has been decomposed into the following effects:

- *Total effect*: Scenario outcome; assumes removal of all fertiliser and biofuels reference policies.
- *Input subsidies effect*: Isolates the impacts of removing only input subsidies for both domestically produced and imported fertilisers (namely supports given to farmers when using fertilisers).
- *Output subsidies effect*: Isolates the impacts of removing only output subsidies for fertilisers (namely support given to fertiliser producers).
- *Biofuel mandates*: Isolates the effects of assuming that no biofuel blending mandates are in place.
- *Biofuel budgetary support*: Isolates the effects of assuming removal of tax incentives and other budgetary measures.
- *Border effect*: Isolates the impacts of removing the different border measures applied in fertiliser and biofuel markets. Specifically, these include
  - import tariffs for fertilisers,
  - import tariffs for biofuels,
  - export taxes for biofuels (applied only in Argentina).

Marginal scenarios

The impacts of the policies removed under the main counterfactual scenarios are further investigated in terms of their marginal effects. Following the decomposition of policies shown above, the marginal scenarios examine the impacts of reducing by 1% ad valorem equivalent rates of the following policy measures:

- Import tariffs for biofuels: Identifies the marginal effect of biofuel import tariffs.
- Import tariffs for fertilisers: Identifies the marginal effect of fertiliser border policies.
- Input subsidies for fertilisers: Identifies the marginal effect of input subsidies to domestically produced and imported fertilisers.
- Output subsidies for fertilisers: Identifies the marginal effect of fertiliser output subsidies.
- Biofuel mandate subsidy equivalent: Identifies the marginal effect of the subsidy equivalent of biofuel mandates.
- Biofuel budgetary support: Identifies the marginal effect of tax incentives and other budgetary measures.

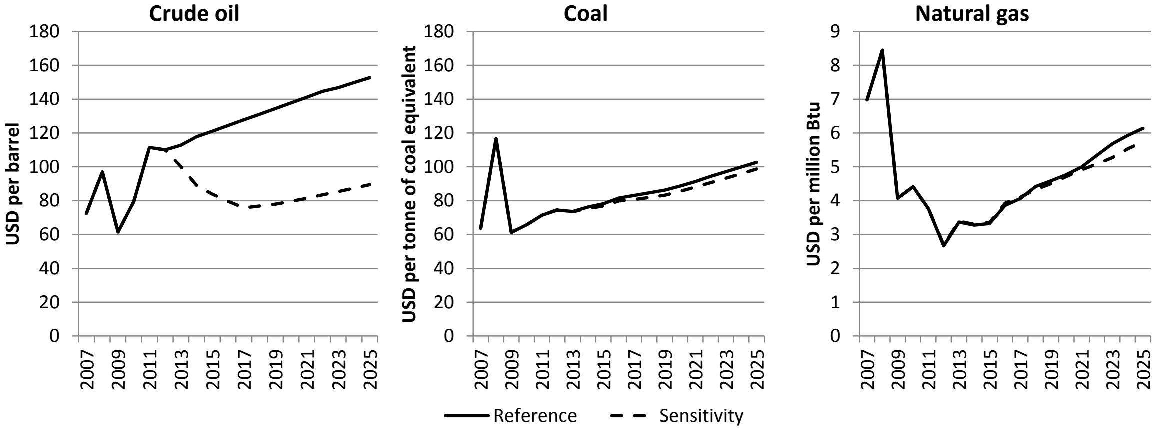
The marginal effects are derived from a series of policy simulations of the multilateral reduction of all *ad valorem* import tariffs for fertilisers and biofuels by 1% and a decrease in the initial fertiliser input and output subsidies by 1%. The simulated biofuel mandates are quantitative measures, but correspond to an equivalent subsidy to biofuel use that allows filling the mandate. A 1% reduction in this subsidy equivalent was also simulated. Multipliers show the effects on global farm incomes (capital and labour) in USD per USD of global value of given support measures, as calculated from these *marginal* policy simulations.

Sensitivity analysis – energy prices

To a large extent, energy prices drive fertiliser production costs and may influence the demand for biofuels. As a result, energy prices may change the impacts of fertiliser and biofuel policies. Lower energy prices, for example, may adversely affect the competitiveness of biofuels in the markets for transport fuels and may increase the impacts of biofuel policies on agricultural markets. They may, however, reduce fertiliser prices paid by farmers (due to lower production costs) and hence decrease the impacts of fertiliser input subsidies on agricultural markets.

Sensitivity analysis on energy prices identifies differences in the way fertiliser and biofuel policies affect agricultural markets under alternative energy prices. The reference scenario assumes relatively high crude-oil prices which tend to make biofuels more competitive relative to fossil fuels (Section 4.2). Here we assume that crude-oil prices will fall to USD 89 per barrel by 2025 (Figure 2). The scenario is based on US EIA (2013), and takes into account expected developments in the future demand and production decisions of the Organization of the Petroleum Exporting Countries and of non-OPEC countries. Natural gas and coal prices are assumed to reach USD 5.7 per mm Btu (USD 5.4 per GJ) and USD 98 per tonne of coal equivalent (USD 3.3 per GJ) respectively, as Figure 2 shows (US EIA, 2013).[22]

Figure 2. Nominal energy prices in energy-prices-sensitivity analysis, 2007-2025



Notes: Crude oil prices refer to Brent crude oil, coal to US delivered coal and natural gas to prices at Henry Hub; natural gas prices are displayed in the secondary vertical axis

Source: OECD-FAO (2013); US EIA (2013); World Bank (2013).

A new reference scenario is therefore developed which assumes only that there will be different (lower) energy prices, whereas the effects of the fertiliser and biofuel policies are analysed in a new counterfactual scenario relative to the lower energy price reference.

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[22] See footnote 16 above on regionally segmented gas markets.

Sensitivity analysis: Imperfect competition

The preceding scenarios assume perfect competition in all markets. A study by Hernandez and Torero (2011), however, suggests that fertiliser markets are concentrated. Having few and big fertiliser producers on the one side and many fertiliser consumers (farmers) on the other side may suggest an oligopolistic market structure. However, there is a difference between nitrogen on the one hand, and phosphorous and potassium on the other hand, as the number of nitrogen suppliers is relatively large. Phosphorous and potassium, on the other hand, are mined products and production is often located close to natural reserves which are concentrated in few countries. Therefore, the market for nitrogen is assumed to approach perfect market conditions, whereas some degree of market imperfection could be imagined in phosphorous and potassium markets. As the degree of market imperfection is unknown, an ad-hoc sensitivity analyses is performed to see the impacts of the simulated policies on intermediate input use.

Market imperfection is introduced in a stylized way as there is a lack of empirical information on some key parameters, such as the actual degree of any market imperfection or the price elasticity of demand for phosphorous and potassium. A mark-up on fertiliser prices is introduced, and the sensitivity analyses is performed by simulating a 1% decrease in the initial fertiliser input and output subsidies in a situation with and without imperfect competition (i.e., with and without the price mark-up). The simulations show the pass-through of changes in fertiliser subsidies on the cost of intermediate input use under imperfect competition in comparison to the perfect competition case.

4. Implications of fertiliser and biofuel policies for agricultural markets and incomes

This section presents the simulation results of the reference and main counterfactual scenarios. Key developments of the reference scenario from 2007 (the base year of the simulations) to 2025 (the end year of the simulated period) are discussed first. Subsequently, the policy impacts are discussed per topic of the counterfactual scenarios for the year 2025. The results are reported for the year 2025 and refer to differences relative to the reference scenario, which hence serves as a comparison point. The total effect of the counterfactual scenario is decomposed to effects stemming from abolishing input and output subsidies for fertilisers, output subsidies for biofuels, biofuel mandates, import tariffs for biofuels and fertilisers as well as export taxes for biofuels as described above.[23]

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[24] in GDP continues to fall worldwide between 2007 and 2025 (Figure 3). The importance of agriculture in GDP is

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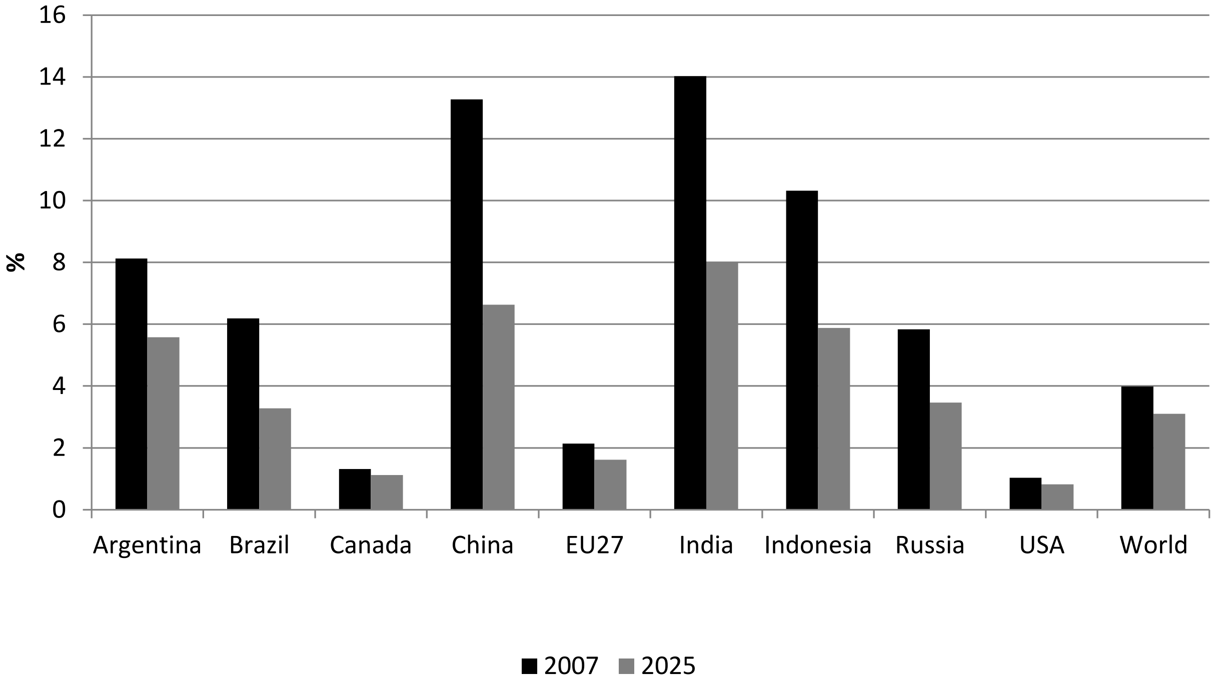
[23] Input subsidies for biofuels, such as support to biofuel storage or transport in Canada and the United States, are discontinued after 2013 and are therefore not considered in this analysis.

[24] Hereafter primary agriculture refers to the first ten commodities listed in Table A.2.

lower in developed countries such as Canada, the EU and the United States and higher in developing and emerging economies such as Argentina, China, India, Indonesia, and the Russian Federation. 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.

Driven by growing population and incomes and accentuated by various support policies, global agricultural crop production is projected to increase strongly between 2007 and 2025 (Figure 4). At a global level, oilseeds – stimulated by strong demand from the biodiesel sector – are projected to show the highest growth (55%). Wheat and paddy rice production, key food crops, also show strong growth with 50% by 2025 and are impacted by fertiliser-related support in key production regions such as the Russian Federation, China, Indonesia and India. The growth of livestock markets is more responsive to income growth than crops and is the highest in countries such as China and India – key markets on both the production and domestic consumption side.

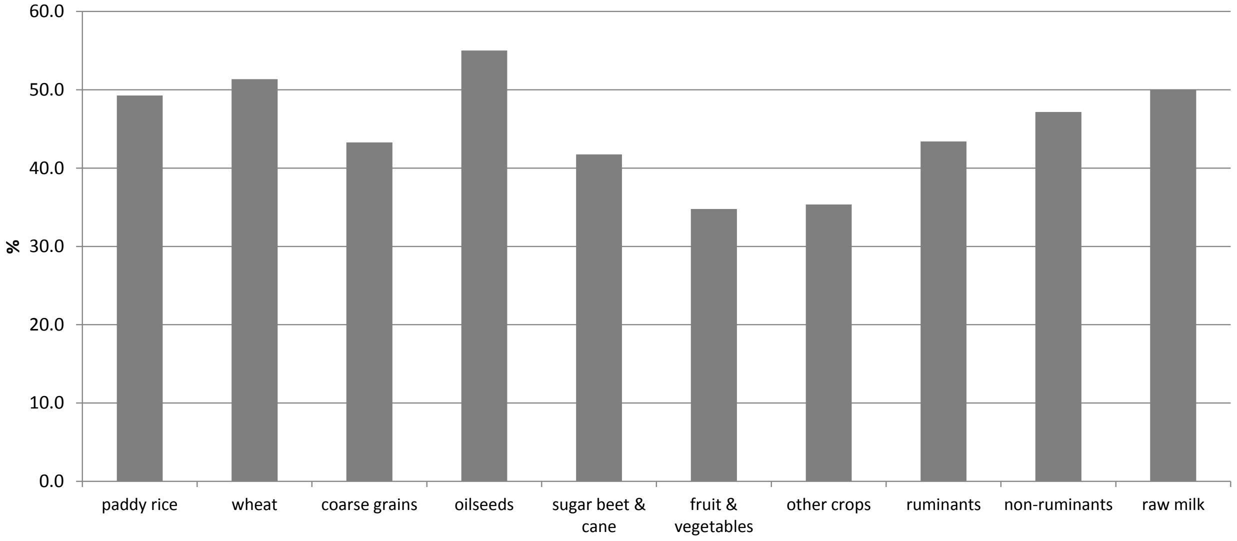
Figure 3. Share of agriculture in GDP, reference scenario



Source: MAGNET simulation results.

From a country perspective, China, India, and Indonesia are the countries with high growth of agricultural production. In other regions, including the EU and the United States, only some crops show significant growth potential; in the EU, the biggest potential is in oilseed production and in the United States in coarse grains production. Both of these commodities are used as biofuel feedstock.

Figure 4. Growth in world agricultural production, reference scenario, 2007- 2025



Source: MAGNET simulation results.

Real agricultural feedstock prices in 2025 are projected to be some 6% lower than those observed in 2007, which were at historically high levels. This is due to the assumed high (labour-saving) technical change in agriculture relative to other sectors and inelastic demand for food (see Robinson et al., 2014).[25]

The reference scenario projects that biofuel mandates are binding in all countries apart from Brazil and that in the EU a blending target of 7% is reached from first-generation biofuels. Biodiesel and ethanol prices increase modestly relative to those of fossil fuels, despite the assumed biofuel mandates. This is due to relatively cheaper feedstock prices compared with fossil energy prices. In Brazil, the share of biofuels in total transport fuel use is projected to increase from 14.8% to 32% (Figure 5). In the reference situation, fossil energy prices increase faster than agricultural commodity prices but the price difference is not sufficient to overcome the initial competitiveness gap between biofuels and fossil fuels, except for ethanol in Brazil.[26] World ethanol production

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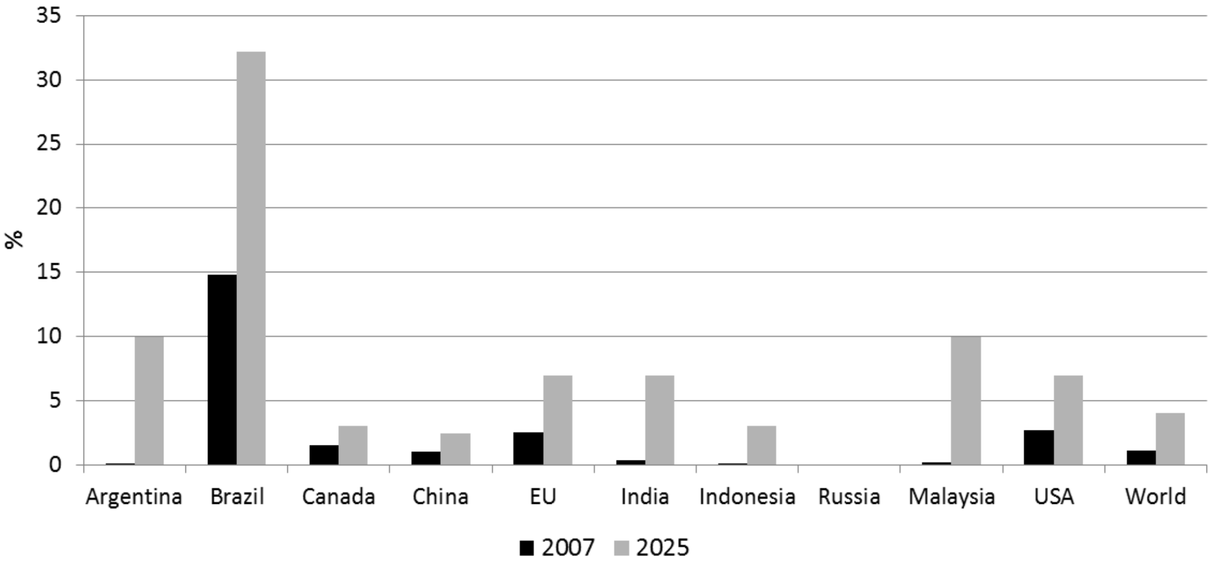
[25] In a global model comparison study on long-term scenarios for agricultural markets, Lampe et al. (2014) show that simulated real agricultural prices for 2030 are in between 16% lower and 16% higher than average prices seen during the mid-2000s. Even though assumptions on GDP, population and energy-prices used here are slightly different, the results of the current study are within this range.

[26] Differences between production costs for ethanol and gasoline prices in 2007 are estimated at 4% for Brazil, 30% for both India and Indonesia, 40% for the United States and 50% for the EU, while the production costs for biodiesel are calculated to be almost 50% higher than fossil diesel prices in most countries. In the reference scenario, these gaps between fossil fuel prices and biofuel prices on

increases by 7% p.a. over the period 2007 to 2025, with biodiesel increasing by 8% p.a. over the same period. Most of the increase however already took place. Between 2007 and 2010 world ethanol and biodiesel production increased by 14% and 17% p.a. respectively.

Figure 5. Shares of biofuels in total transport fuel use, reference scenario



Source: MAGNET simulation results.

Developments in fertiliser prices and in particular in nitrogen prices, are driven by the development of natural gas prices as shown in Figure 1, which are assumed to fall by 36% between 2007 and 2025. As mentioned above, natural gas represents the bulk in the production costs notably of nitrogen fertilisers. In consequence, nitrogen fertiliser prices tend to fall relative to phosphorous and potassium prices.

Production of all three fertiliser macronutrients is projected to grow by more than the rate of agricultural commodities. The global production of nitrogen, phosphorous and potassium is assumed to grow by 4.0%, 3.1% and 2.9% p.a. respectively. The higher growth rate of nitrogen is due to the decreasing gas price. Production of phosphorous and potassium, which are mining products, is less affected by changes in natural gas prices. Fertiliser use in agriculture increases between 2007 and 2025 by the same rates as fertiliser production, suggesting the intensification of agricultural production.

Implications of fertiliser and biofuel policies for agricultural markets and incomes

This section discusses the implications for agricultural markets and incomes from a hypothetical simultaneous removal of fertiliser and biofuel policies, as simulated with the MAGNET model. Most of the results are shown relative to the reference scenario discussed above. In order to allow for a better understanding of the contributions various policy categories make to the overall effects, the total effect is decomposed as described in Section 3. While the various elements of the supply chains (from fertilisers through agricultural production, prices and income to downstream biofuel markets) are

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the global level decline by 17% for biodiesel and by 27% for ethanol. Key assumptions underlying the biofuel production cost calculations can be found in Annex 1.

interdependent, the discussion of the effects first focusses on the two markets shocked by policy changes, i.e. fertilisers and biofuels, before moving on to the implications for agricultural supply, land use, and agricultural prices. Finally, implications for agricultural incomes are discussed.

The graphical representation of results follows a largely standardized approach. In order to make the figures more readable the selection of policy categories shown depends on the results: elements with very small implications compared to other policy categories therefore are not always shown.

Implications for fertiliser markets

A removal of fertiliser subsidies, both those paid to fertiliser producers and those to farmers, increases the cost of fertiliser use for farmers. In the case of input subsidies, the subsidies are paid directly to farmers to offset high market prices for fertilisers. A removal of input subsidies therefore leads to a decrease in the demand for fertilisers. In the case of an output subsidy, the support is given to the fertiliser industry. A removal of output subsidies increases the fertiliser price, leading in turn to a decrease in demand for fertilisers. Figure 6 shows the impact of the policy shock (removal of all biofuel and fertiliser support) on fertiliser demand. The use of fertiliser decreases in the four countries with fertiliser subsidies: China, India, Indonesia, and the Russian Federation. The impact is most pronounced in Indonesia. There, the fertiliser subsidy was rather high (an implied subsidy rate of 68%) and its removal leads to a decline in agricultural fertiliser use by more than 50%.[27]

The removal of import tariffs should make the importing of cheap fertilisers more attractive and thus it can be expected that the demand for fertilisers would increase. However, Figure 6 shows that the impacts of removing fertiliser tariffs are generally negligible. In most countries, the impact of removing the import tariffs is hardly noticeable because the prevailing import tariffs are quite small.

The removal of biofuel mandates and biofuel budgetary support policies have an indirect impact on fertiliser demand. The production of biofuel feedstock increases significantly because of the biofuel policies. If the biofuel mandate is abolished or no support is given to the biofuel sector, the demand for biofuel feedstock can be expected to decline, leading to a decline in the demand for fertiliser by agricultural segments that produce biofuel feedstock (see further below). Figure 6 shows that the demand for fertilisers does indeed decrease in most countries due to the removal of biofuel mandates.

The policy shock has no implications for the nutrient composition of fertilisers used. The model assumes that the three fertiliser nutrients are complementary, leaving the balance between the three nutrients unchanged. Consequently, relative changes in prices to farmers do not affect the choice between the different types of nutrients.

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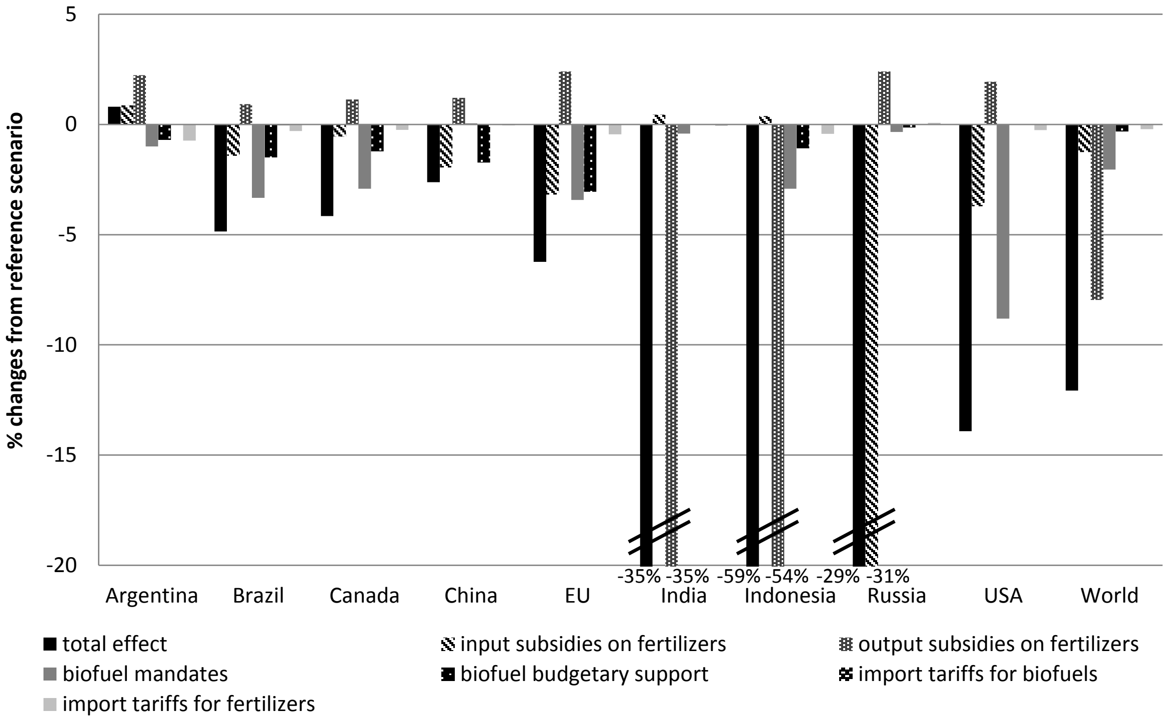
[27] Apart from raising crop production, high fertiliser use may have negative implications for farmers' health or the environment if over- or misused. As indicated above, regulatory policies in numerous countries aim at limiting such impacts. Analysing such effects related to fertiliser support policies is, however, beyond the scope of the present study.

Figure 6. Impacts on fertiliser use, counterfactual scenario, 2025



Notes: Effects shown represent the following changes:

Total effect: assumes removal of all fertiliser and biofuels reference policies

Input subsidies on fertiliser effect: only removing input subsidies for the use of fertilisers (both domestically produced and imported; including input-cost related area payments in China), while all other policies remain unchanged.

Output subsidies on fertiliser effect: only removing subsidies to fertiliser producers, while all other policies remain unchanged.

Biofuel mandates: only removing biofuel blending mandates.

Biofuel budgetary support: only removing biofuel budgetary support and tax exemptions on biofuel consumption.

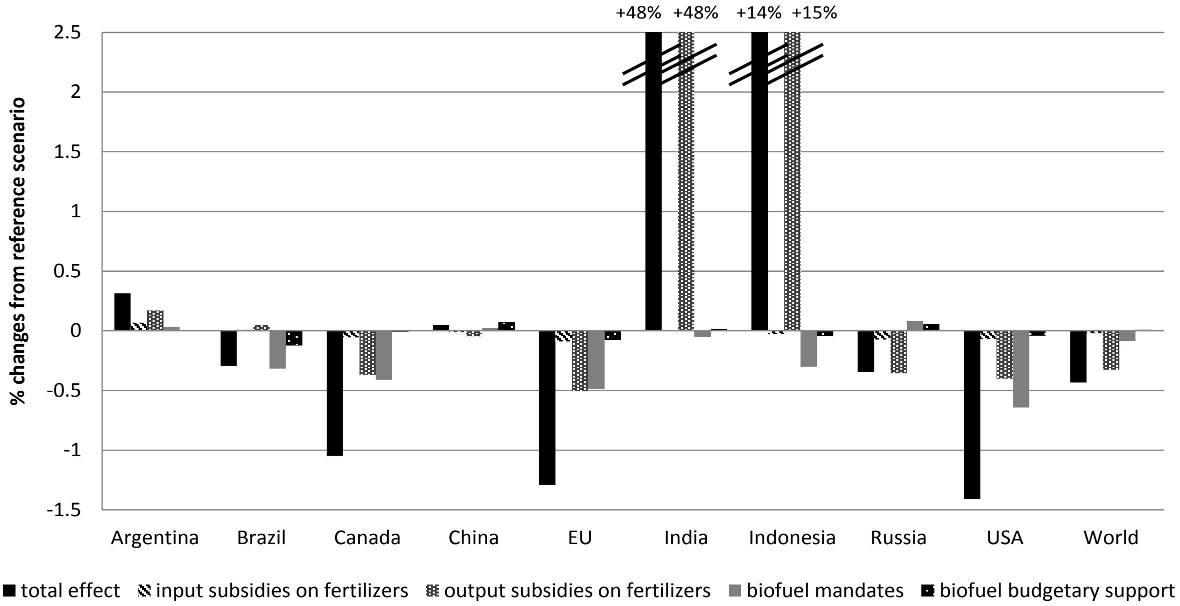
Import tariffs for biofuels: only removing import tariffs for biofuels.

Import tariffs for fertilisers: only removing import tariffs for fertilisers.

Source: MAGNET simulation results.

Fertiliser support can have opposite effects on fertiliser market prices depending on how the support is given. In India and in Indonesia, the fertiliser industry receives a subsidy offsetting its high energy prices while in China and the Russian Federation farmers receive support to lower the burden related to high fertiliser prices (and, in China, those of other inputs). If the subsidies are given to the farmers it can be expected that the prices received by the fertiliser industry will drop after the subsidy is abolished, following the decline in fertiliser demand. Figure 7 shows the price effects of the different policies. When the subsidies on fertilisers are abolished, the cost of fertiliser to the agricultural sector increases, thus reducing farmers' demand for fertilisers. As a consequence, the price of fertilisers received by the industry declines. In general this negative price effect is modest. In India and in Indonesia, the effect is different. Because the fertiliser subsidy is given to the fertiliser industry, the elimination of this subsidy increases the market price. If all (output) subsidies to fertiliser industry were to be abolished in India and Indonesia, the market price of fertiliser in these countries would increase by 48% and 15%, respectively. In both countries, fertiliser subsidies offset a large part of fertiliser production costs (Table 5). As India has limited land reserves, the more expensive fertiliser cannot be substituted by new area, resulting in the price increase to be even larger than in relatively land-abundant Indonesia.

Figure 7. Impacts on fertiliser market prices, counterfactual scenario, 2025



Note: For explanations on the individual effects shown, see note to Figure 6.
Source: MAGNET simulation results.

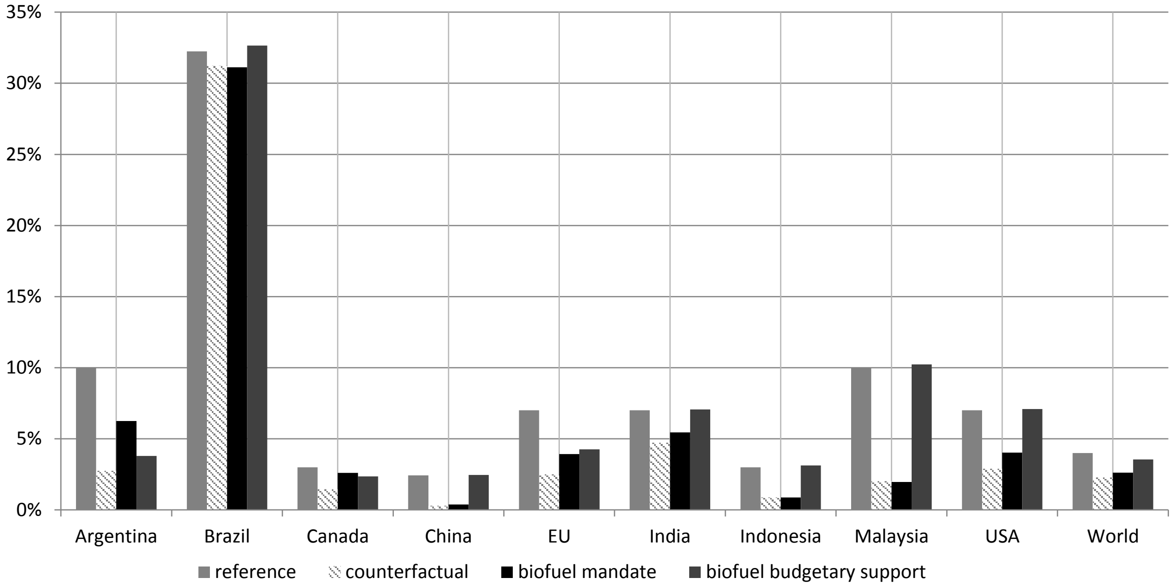
In most countries where biofuel mandates are implemented (i.e. Brazil, Canada, EU27, Indonesia, and United States), the fertiliser prices are affected also by the elimination of the biofuel mandates, next to the elimination of fertiliser subsidies. In order to comply with the biofuel mandate, a large quantity of biofuel feedstock has to be produced for which a large quantity of fertiliser is required. If the biofuel mandates are abolished, the biofuel feedstock market collapses as does the demand for fertiliser, leading to a price decline in fertiliser.

Implications for biofuel markets

Eliminating binding biofuel mandates and biofuel budgetary support policies results in falling demand for biofuels. In several countries, mandates are complemented with tax concessions and other budgetary measures (Table 2), thus shifting the cost of maintaining the biofuel mandate from the fuel consumer to the taxpayer. A removal of mandates and budgetary support would result in much lower biofuel use in most countries (Figure 8) due to higher production costs of biofuels compared to fossil fuels under the assumed crude-oil price.

Interestingly, the biofuel share in Brazil also falls. Brazil is the only country in which ethanol production is competitive at given fossil fuel prices, thus the drop cannot be explained by non-competitive production. The biofuel share in Brazil drops because Brazil stops consuming biodiesel but continues to consume ethanol. Removal of budgetary support reduces biofuel demand particularly in export markets (such as the EU), and hence biofuel prices, thus slightly increasing the domestic use of biofuels in Brazil.

Figure 8. Shares of biofuels in total transport fuel use, reference and counterfactual scenarios, 2025



Note: Biofuel shares are shown for four different scenarios: reference scenario (fertiliser and biofuel policies in place), counterfactual (fertiliser and biofuel policies removed), biofuel mandate (only biofuel mandates removed while budgetary support and fertiliser policies kept in place), biofuel budgetary support (only biofuel budgetary support removed while mandates as well as fertiliser policies, kept in place).
Source: MAGNET simulation results.

Since the demand for biofuels declines due to the elimination of biofuel mandates and biofuel budgetary support, both prices and the production of biofuels are expected to decline. A drop in biofuel production is observed in all countries, as shown in Figure 9. In countries where the biofuel mandates are binding, abolition of both mandates and budgetary support significantly decreases biofuel production because it is not competitive with fossil fuels at crude oil prices assumed here. The decline in biofuel production in Brazil is comparatively small. Brazil loses most of it exports of biofuels, whereas the domestic consumption of biofuels is, as discussed above, little affected.

Countries without a biofuel mandate and biofuel budgetary support policies are also affected by the elimination of the biofuel policies. Due to mandates and other demand-enhancing policies, the world prices of biofuels were raised above their undistorted levels. Biofuel producers in these countries benefited from these high prices even if domestic use may be reduced. When mandates are abolished, the world prices for biofuels collapse, causing the biofuel production to decline also in countries without mandates. The impact in these countries without biofuel policies is found to be quite strong in relative terms; however, it should be kept in mind that the absolute value of biofuel production in these countries is rather small (Figure 9).

There is also a difference in the impact of the abolition of biofuel mandates and the elimination of biofuel budgetary support policies. At global level as well as in most individual countries, biofuel mandates have a stronger effect than the budgetary support policies. However, in a few countries, including Argentina[28] and Canada, the elimination of budgetary support policies are more dominant than the mandates.

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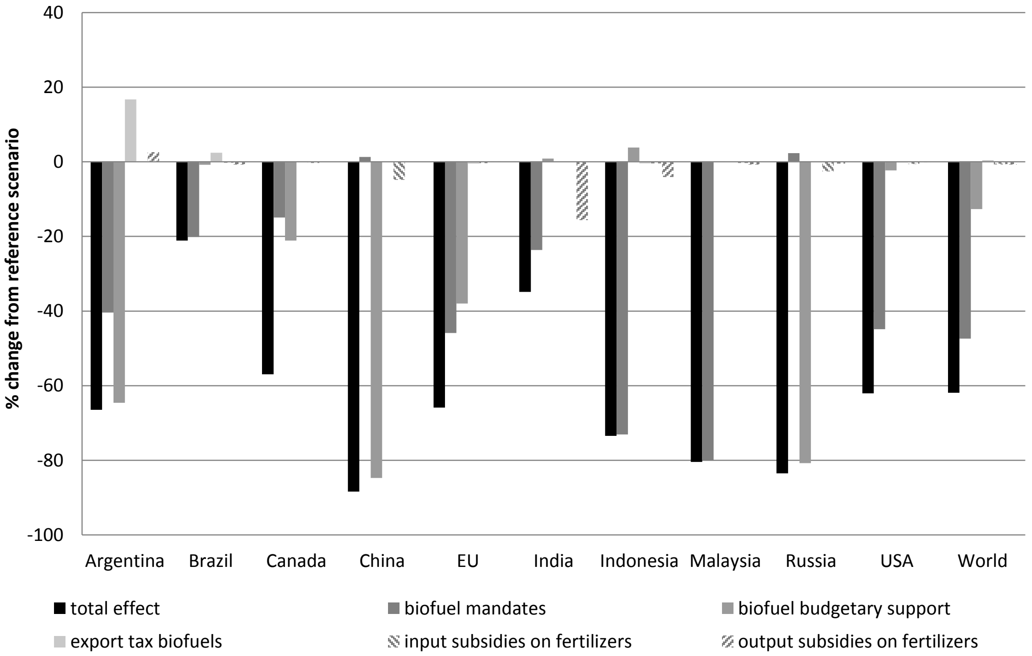
[28] See Footnote 19 for a caveat on Argentine budgetary biofuel support.

The impact of abolishing the import tariffs on biofuel production is far smaller. Biofuel producers in both Brazil and the United States benefit slightly from the abolition of import tariffs. Surprisingly, Argentina reduces its production of biofuels when import tariffs on biofuels are abolished, despite being a net exporter of biodiesel. Both Argentina and the United States export biodiesel mainly to the EU. In the reference scenario there is an import tariff from the United States to EU for biodiesel, but no import tariff from Argentina to the EU for biodiesel. Therefore, by abolishing the import tariffs for biofuels, the demand for the cheaper biodiesel from the United States increases, causing Argentina to lose some of its export market.

The elimination of the Argentinian biodiesel export tax leads to an increase in domestic biodiesel production in Argentina: biofuel output would be 17% higher without the tax compared to the reference situation with the export tax maintained (Figure 9).

The elimination of fertiliser input subsidies also has some indirect impact on the production of biofuels. Biofuel feedstock prices increase, which leads to higher production costs of biofuels, which negatively impacts the production of biofuels. This effect is visible in India, China, Indonesia and the Russian Federation. Overall, however, biofuel production is mainly driven by the biofuel mandates; all other policies we consider have only a comparatively small impact, with the exception of the large Indian fertiliser support.

Figure 9. Impacts on biofuel production, counterfactual scenario, 2025



Note: For explanations on the individual effects shown see note to Figure 6.

Source: MAGNET simulation results.

Implications for agricultural supply and demand

Figure 10 shows the decomposed impacts of abolishing fertiliser and biofuel policies on agricultural production. At the global level, primary agricultural production drops by

1.1%. Most of that decline is related to abolishing biofuel mandates, although the large fertiliser support notably in India and Indonesia also plays and important role.

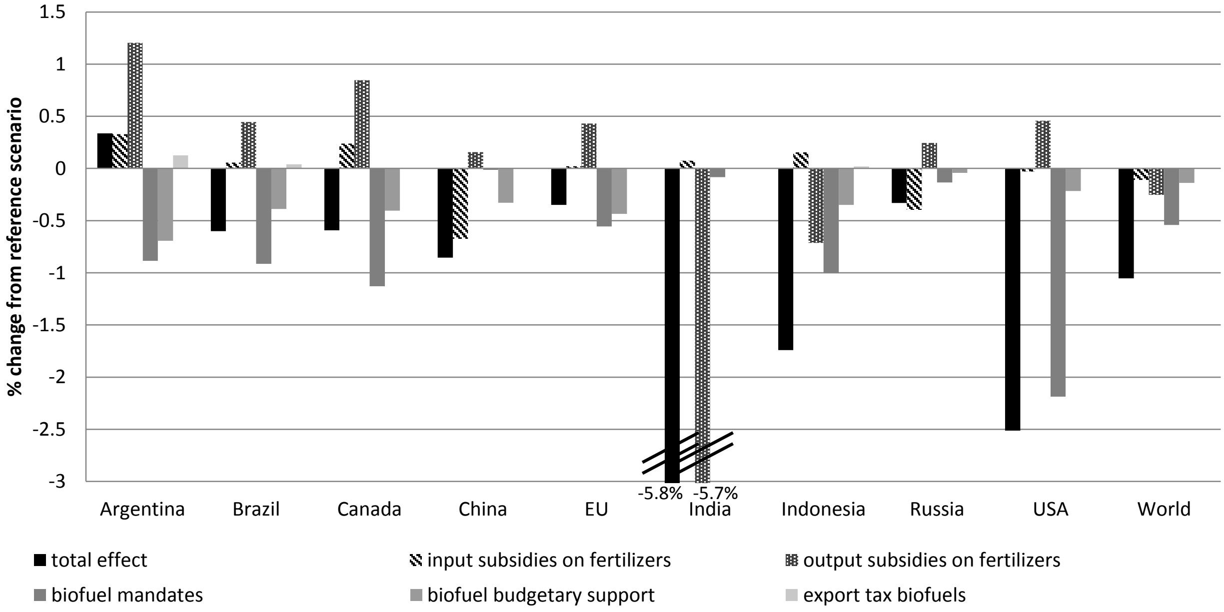
The effects on agricultural supply and demand differ by region and depend on the existing policy focus and the crops farmers produce. The simulation eliminated fertiliser subsidies paid to farmers in China and the Russian Federation. Abolishing these subsidies makes fertilisers more expensive for farmers in these countries, who reduce their fertiliser use and hence their agricultural supply. In China, the input-related area payments (modelled to be linked to both land and fertiliser use) also have a relatively strong effect on agricultural production. In India and Indonesia, in contrast, fertiliser subsidies are paid directly to the fertiliser industry, with the output subsidies on fertilisers 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 5). Abolishing these subsidies increases fertiliser prices and leads to higher production costs for farmers, who respond by decreasing agricultural production by around 5.6% in India. The production effects are less significant in Indonesia where the more expensive fertilisers can be substituted more easily by additional land use; still, a removal of fertiliser subsidies would reduce agricultural output by 0.7%. These effects are shown in Figure 10, in the bars reporting the effects from abolishing only fertiliser input subsidies and only fertiliser output subsidies. Agricultural demand is not affected directly. As the cost share of fertilisers in primary agriculture is modest, the increase in agricultural prices due to a removal of fertiliser subsidies is limited in most cases.

Abolishing only biofuel mandates and biofuel budgetary support policies reduces biofuel production and leads to lower demand for biofuel feedstock commodities, namely for wheat, coarse grains, sugar beet and cane and oilseeds. The latter is caused by the lower demand for crude vegetable oil. Supply of biofuel feedstock adjusts downwards at world level (shown in Figure 11), whereas at the regional level the effects are not only due to a decrease in domestic demand but also resulting from falling import demand for biofuel feedstock in those countries where biofuel mandates are abolished in the counterfactual scenario. The effects in Brazil, Canada, the EU, Indonesia and United States are caused mainly by the lower domestic demand, whereas the effects in Argentina are a result of lower exports to the above mentioned countries.

Removing fertiliser subsidies dominates the changes in agricultural production in Argentina, China, India and in the Russian Federation, whereas removing biofuel mandates dominates the effects on the agricultural sector of Brazil, Canada, the EU and the United States.

Figure 11 shows the changes in world supply of individual crops when abolishing the simulated fertiliser and biofuel policies. The decline in the oilseed production is mostly due to responses in Canada, in the EU and in South American countries, as a result of abolishing the biofuel mandates. Changes in sugar beet and cane production are due to reduced ethanol production in Brazil and in the EU, whereas changes in coarse grains are mainly driven by lower ethanol production in the United States. The decline of the wheat sector is driven by developments in China and in the Russian Federation due to the elimination of fertiliser input subsidies. Production of paddy rice, a key staple commodity in some of the countries providing fertiliser subsidies, remains largely unchanged due to

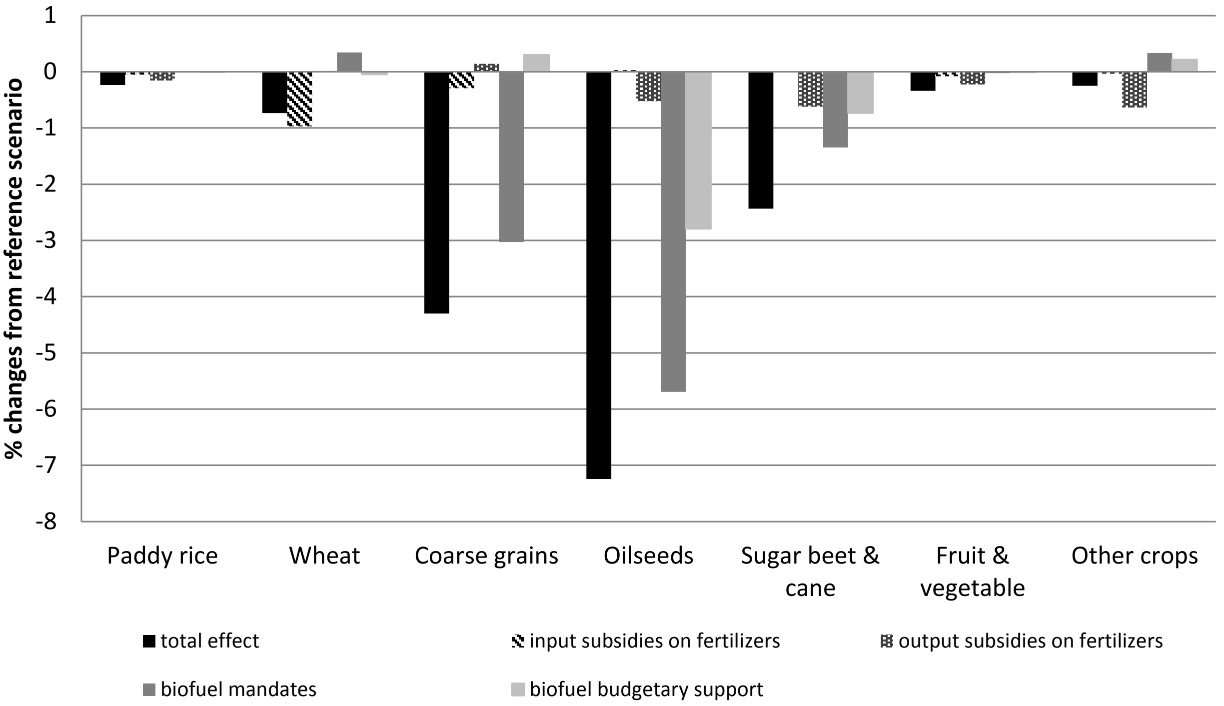
Figure 10. Impacts on primary agricultural production, counterfactual scenario, 2025



Note: for explanations on the individual effects shown see note to Figure 6.

Source: MAGNET simulation results.

Figure 11. Impacts on world crops production, counterfactual scenario, 2025



Note: for explanations on the individual effects shown see note to Figure 6.
Source: MAGNET simulation results.

the inelastic demand – most of the effect is found in rice prices rather than in rice output. The same argument also holds for fruit and vegetables, a key product group in Chinese agriculture.

Abolishing biofuel and fertiliser policies has more limited effects on livestock production than for crops (Figure A.6). Global livestock production is found to hardly change. This aggregate masks, however, some changes at regional level. Argentina, Brazil and the United States would see slightly higher livestock output, given the lower prices for feedgrains that would prevail without biofuel policies. India, in contrast, would reduce output as an elimination of fertiliser support would lead to higher feed prices. Most of these effects are, however, no larger than about half a per cent, with the exception of India (-2.6%).

Implications for agricultural land use

Abolishing fertiliser and biofuel policies has only small effects on global agricultural land use. A simultaneous removal would increase total land use by some 0.2%, representing about 10 million hectares. This total may be within the margin of uncertainty for this type of analyses. The compound effect masks, however, that fertiliser and biofuel policies affect agricultural land use in opposite directions, and that for some regions significant land use changes are found. Figure 12 shows the effects of removing the simulated policies on agricultural land use.

Removing fertiliser subsidies – both input and output – increases the costs of fertiliser use for farmers, as discussed above. They respond by lowering their fertiliser use in crop production, which in turn decreases crop yields. The sector therefore substitutes fertilisers with land in order to maintain agricultural production. This effect is particularly pronounced in Indonesia due to the high fertiliser subsidies paid to the industry in the reference scenario, and linked to the availability of land in the country.[29] The effect is also more pronounced in countries which have larger land reserves suitable for agricultural production, such as in Brazil, Canada, the Russian Federation and, to a lesser extent, Argentina and the United States (Figure 12). In these countries land can generally move into or out of production as land demand changes (see van Meijl et al., 2006). In China, input subsidies are directly linked to the land use itself. Abolishing these subsidies therefore leads to slightly reduced land use for agriculture. In India there is hardly any effect on agricultural land use despite the magnitude of its fertiliser support, as in India all agricultural land is in use. In India changes in demand for land lead mainly to different land rental rates (Annex 1).

Removing biofuel mandates and budgetary support, however, has the opposite effect on land use. As explained above, crop production and in particular production of coarse grains, oilseeds and sugar beet and cane decreases. While agricultural yields are little affected by these changes, the reduction of production is largely based on releasing land from the agricultural sector – globally by about 0.3% through removing mandates and 0.08% due to removing budgetary support. In the United States, the decrease is linked to the 1.3% decline in the land area used for cultivating coarse grains and oilseeds, while in Canada the land area reduction is linked to a decline in the oilseeds area.

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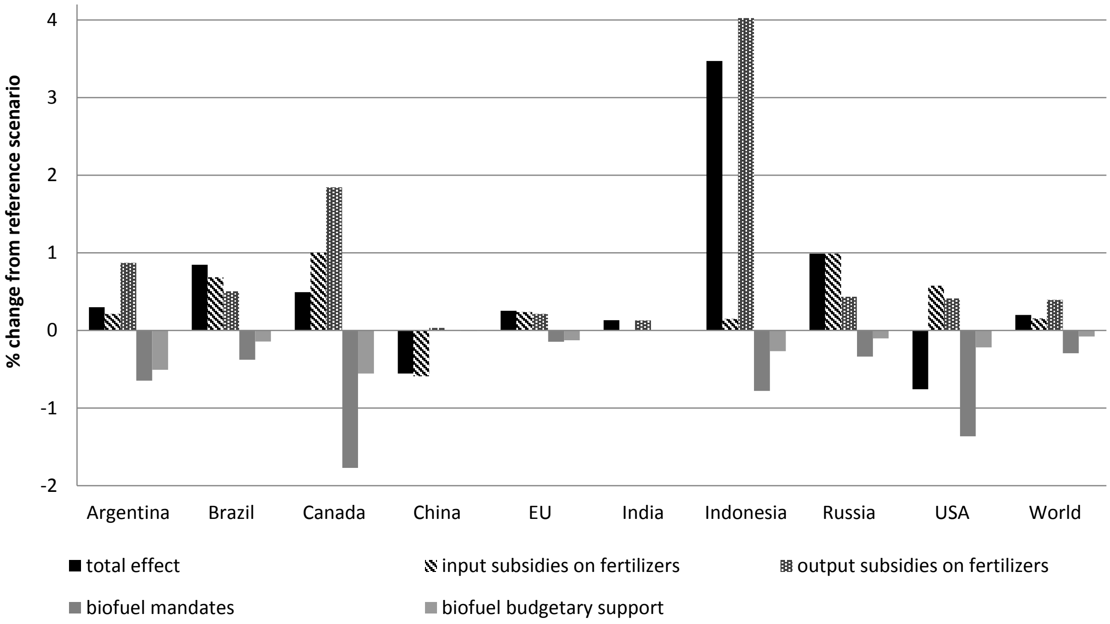
29. The substitution of land for fertilisers potentially also results in a substitution of related environmental consequences. An analysis of the potential environmental effects is, however, outside the scope of this report.

Removing import tariffs for biofuels and fertilisers hardly affects land use because of the rather limited effects on agricultural production. Considering the total effects in the different countries, agricultural land use changes are driven more by the impact of abolishing fertiliser subsidies than abolishing biofuel mandates. The latter drives land use changes mainly in Canada and the United States.

Figure 12. Impacts on agricultural land use, % changes to reference scenario, 2025



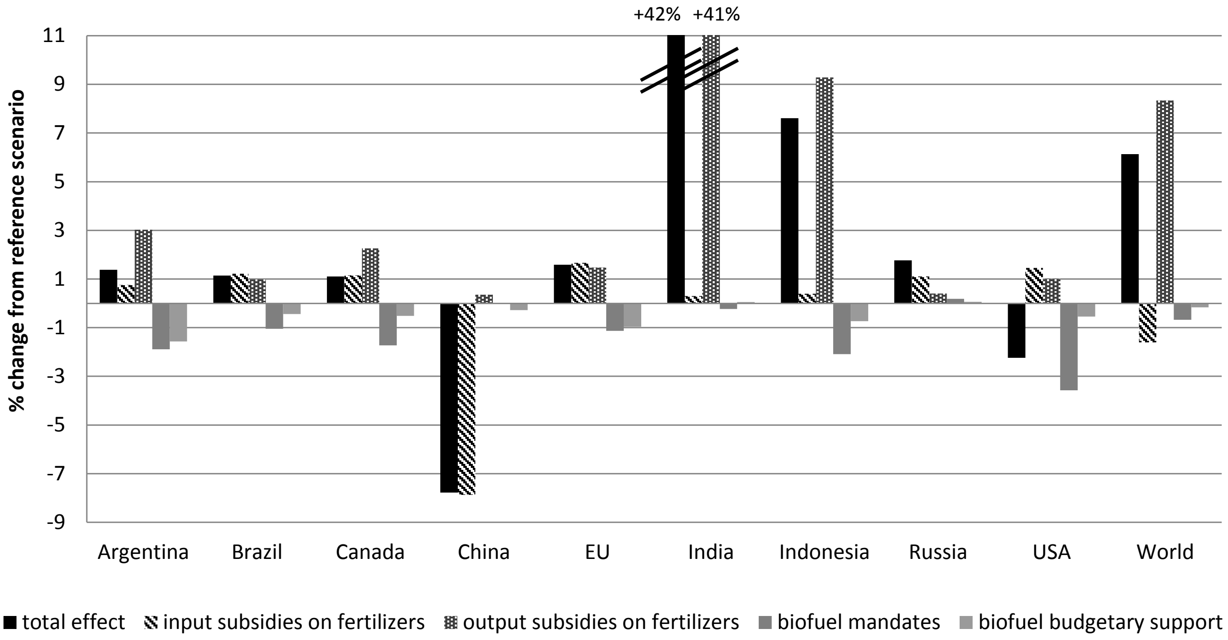
Note: for explanations on the individual effects shown see note to Figure 6.

Source: MAGNET simulation results.

Changes in land use are mirrored in the land value as shown in Figure 13. Overall land value increase when abolishing only fertiliser subsidies — both input and output — due to the increase in agricultural land use to substitute for more expensive fertilisers, as, for example, in Indonesia, India and the Russian Federation. The increase in land rent is comparatively high in Indonesia and notably India, related to the high levels of subsidies provided particularly in these countries, and to scarce land reserves particularly in India. As mentioned above, in China input subsidies are directly linked to the land use itself. Abolishing these subsidies therefore leads to slightly reduced land use for agriculture thus decreasing the value of land by a large part of the land subsidy.

Land values, however, decrease when only biofuel support is removed. Decreasing agricultural land use leads to lower land value. The effect is greatest in United States (decrease of 3.6% due to a removal of biofuel mandates alone), followed by Indonesia (decrease of 2.1%), Canada (decrease of 1.7%) and the EU (decrease of 1.1%).

Figure 13. Impacts on land values, counterfactual scenario, 2025



Note: for explanations on the individual effects shown see note to Figure 6.

Source: MAGNET simulation results.

Implications for agricultural prices

The impacts of abolishing the simulated fertiliser and biofuel policies on agricultural prices are shown in Figures 14 and 15. Decomposition shows that abolishing fertiliser subsidies increases agricultural prices, whereas abolishing biofuel blending mandates decreases them. The effects of liberalising biofuel and fertiliser trade are small, due to the comparatively low initial import tariffs.

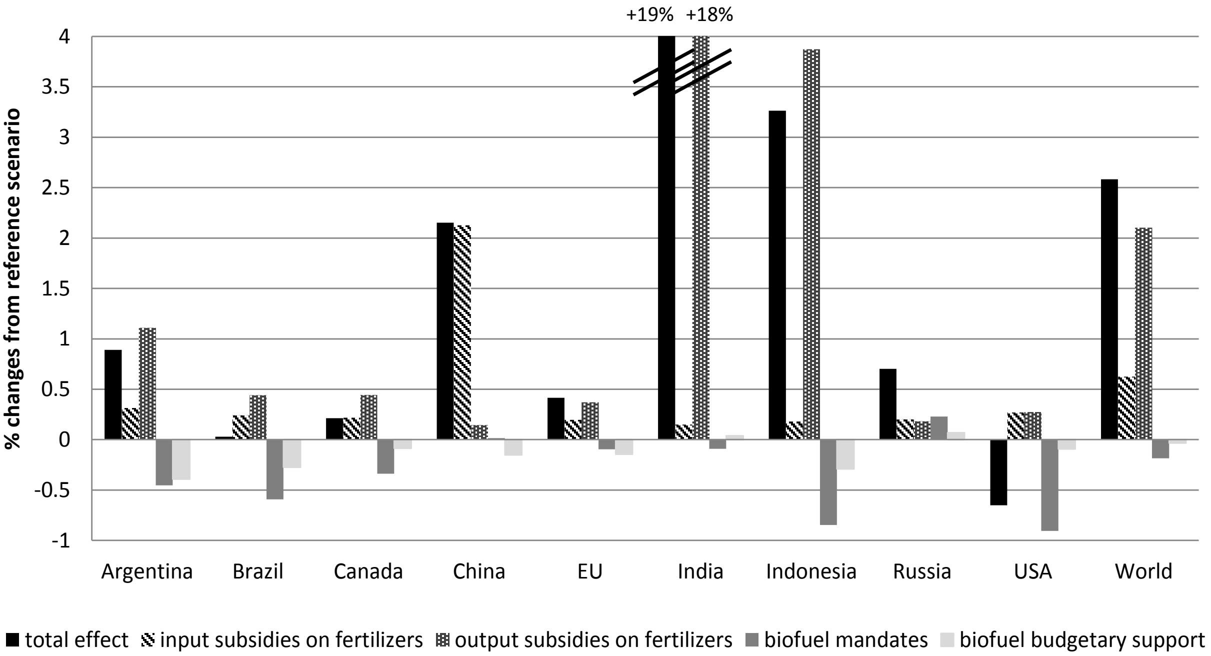
Removing fertiliser subsidies – both input and output – increases agricultural prices following reductions in crop production (see above). These effects are particularly visible in China, India, and Indonesia, countries with high initial fertiliser subsidies (Figure 14).

Removing biofuel mandates and budgetary measures supporting biofuel use reduces demand for coarse grains, oilseeds, sugar beet and cane and, to a lesser extent, wheat, and leads to lower prices for those commodities. This is most visible in Brazil, Canada and the United States (Figure 14). In these countries, abolishing the biofuel mandates causes the sharpest decline of agricultural production (Figure 10). Overall, the impact of biofuel policies on prices for agricultural primary products remains below 1%, however.

In total, abolishing all simulated policies simultaneously would increase agricultural prices in all regions with the exceptions of Brazil and the United States. Generally, the price increasing effect of removing the large fertiliser support exceeds the decreasing impacts from a removal of biofuel support. While this is most visible in China, Indonesia and notably India, it also holds for most other countries due to the higher import demand from those three. In the United States, biofuel support has a stronger impact on agricultural prices, so the total price effect of removing all simulated policies is negative.

Brazil's prices are, on average, largely unaffected as the two effects roughly cancel out each other.

Figure 14. Impacts on agricultural prices, counterfactual scenario, 2025



Note: for explanations on the individual effects shown see note to Figure 6.

Source: MAGNET simulation results.

As shown in Figure 15, removing biofuel mandates affects mainly coarse grains, oilseeds, and sugar beet and cane, commodities used intensively as biofuel feedstock. Similar, but smaller effects can be seen from eliminating budgetary biofuel support: with mandates in place, budgetary support often has a more redistributing rather than distortive effects. Removing biofuel policies (mandates and budgetary support) cause world prices to decline for coarse grains, oilseeds and sugar with respectively 0.8%, 2.2% and 0.6%. The world price of crude vegetable oils declines with 5.2%. These price changes are smaller than those found by some other studies. OECD (2008) for instance estimates the effect of 1st-generation biofuel policies in United States, EU and Canada to be about 3% for oilseeds, 5% for wheat and 7% for coarse grains.[30] Removing fertiliser input and output subsidies tends to increase world market prices of all crops, with the strongest price effects found for paddy rice and sugar crops, followed by oilseeds, fruit and vegetables and wheat.[31] These crops have comparatively high fertiliser input and

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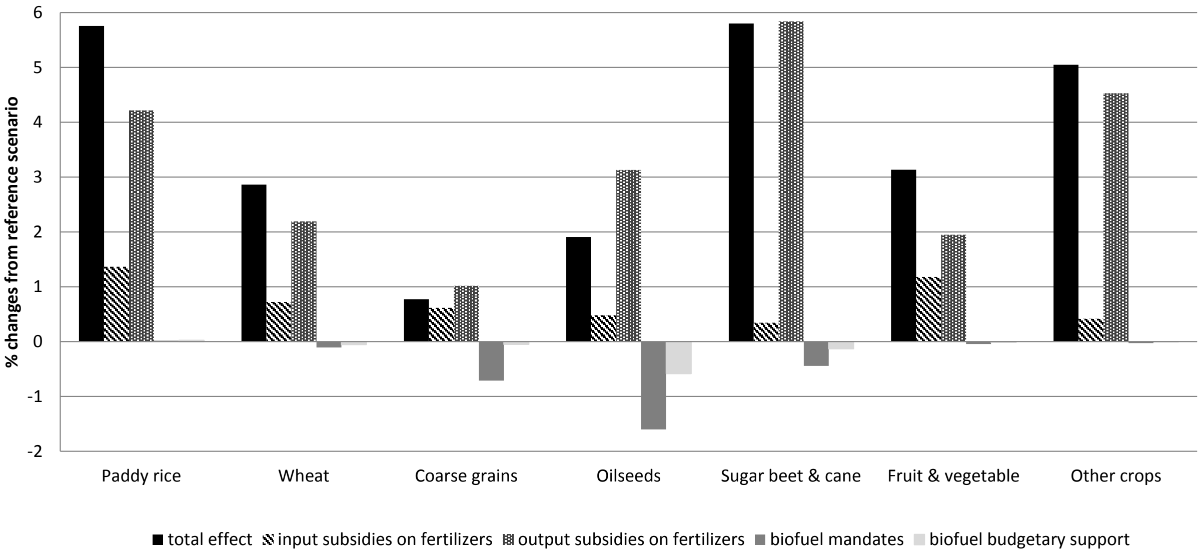
30. The small changes in crop prices are linked to strong substitution between land and fertilisers in agricultural production, causing much of the shock to be absorbed by changes in fertiliser use. As fertilisers to a large extent are linked to the (much larger) energy markets, their prices change only little at the global scale (see Figure 7). As discussed in some detail in Section 3, the substitution elasticity between land and fertilisers is subject to significant uncertainty, so the price results presented here should be taken with caution.

31. It is worth noting that the link between fertiliser and agricultural markets works in both ways, and several studies have shown the importance of agricultural prices as a driver for fertiliser prices. For instance, Ott (2012: p. 27 Table 3) shows that based on vector-autoregression

represent key agricultural products in the four countries providing fertiliser support (rice in China, India, and Indonesia, sugar cane and oilseeds in India, wheat in China and the Russian Federation, and fruit and vegetables in China).

Figure 15. Impacts on crops world market prices, counterfactual scenario, 2025



Note: For explanations on the individual effects shown see note to Figure 6.

Source: MAGNET simulation results.

As for livestock production, livestock prices change only little in most countries, and only moderately at the world level, with an aggregate increase of about 1.2%, largely due to higher feed prices following the removal of fertiliser support. The largest effect is found for India, where livestock prices increase by more than 9% if fertiliser support is eliminated (Figure A.7). The implications from a removal of biofuel support on livestock prices differ across countries: where biodiesel is large compared to ethanol, the elimination of mandates and budgetary support diminishes the availability of oilseed meals, an important protein feed in livestock feed ratios. Countries like the EU and India therefore see livestock prices increasing. A similar impact can be seen in the Russian Federation which provides significant amounts of vegetable oils to the EU. (In Indonesia, where biodiesel is made from palm oil, oilseed meals do not represent a by-product). Other countries with a higher focus on ethanol see average feed prices decline following reduced biofuel production, resulting in lower livestock prices.

Implications for agricultural income

Agricultural income is represented here by value added of labour and capital at opportunity costs. As land is not always owned by farmers, we analyse the income from non-land production factors. Changes to land rents are discussed in the context of implications for agricultural land use above.

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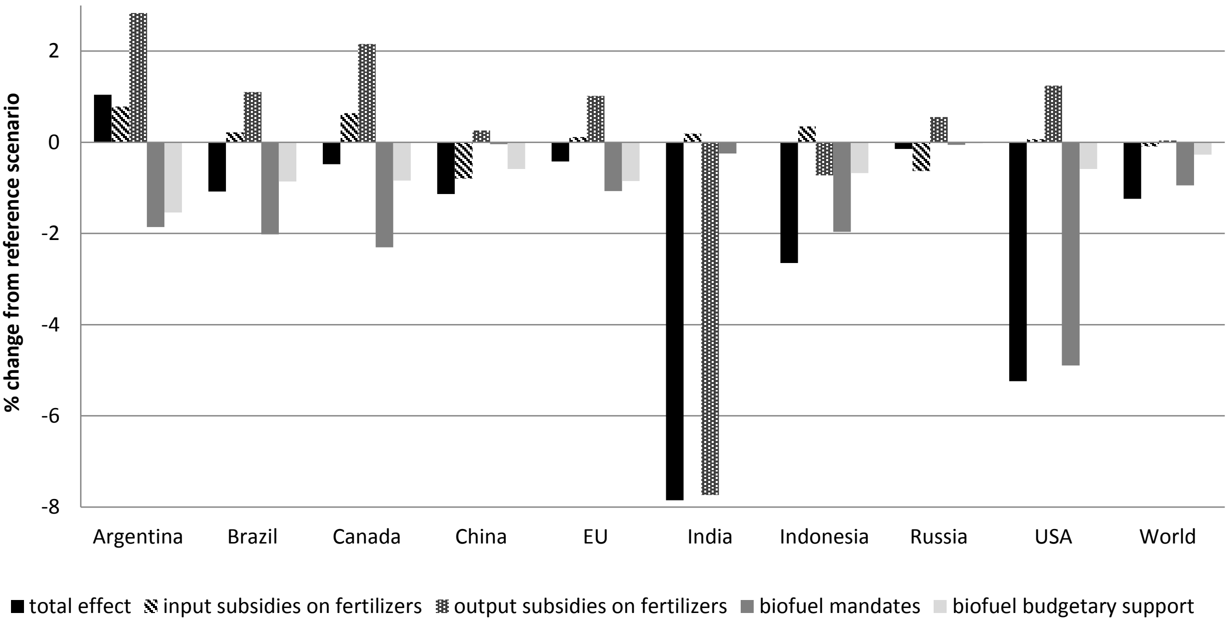
analyses, grain prices are found to Granger-cause changes in fertiliser prices, while fertiliser prices themselves are found to Granger-cause changes in grain prices. In turn, both fertiliser and grain prices are found to be Granger-caused by energy prices.

Figure 16 shows a decomposition of the effects of the various simulated policy changes for non-land based income in the primary agricultural sector. The abolition of fertiliser and biofuel policies has, as expected, a negative impact on income from primary agriculture. At the world level, the impact is equal to about 1.2%. This is predominantly driven by the abolition of all biofuel mandates. Importantly, biofuel mandates and, to a lesser extent, budgetary support benefits not just farmers in the countries providing the support, but also farmers in other countries, even if much less significantly so. Higher prices are transmitted to these other countries and result in increased revenues and incomes of their farms. A removal of the biofuel support therefore has a negative effect on farm incomes around the world.

This is not the case for support policies in fertiliser markets. Removing subsidies currently paid either to fertiliser industries or to farmers reduces incomes in the countries that apply these measures, but benefit farmers elsewhere through higher crop prices. In consequence, while the income effect from removing fertiliser support in individual countries can be similar to, or even higher than, those from eliminating biofuel policies, the global income effect of fertiliser support is much smaller than that of biofuel support.

Figure 16. Impacts on agricultural income, counterfactual scenario, 2025



Notes: for explanations on the individual effects shown see note to Figure 6.
Agricultural incomes are measured as factor value added of labour and capital.

Source: MAGNET simulation results.

For total income effects at the country level, India shows the greatest decline in primary agricultural non-land income of the fertiliser policy using countries. Income in India declines by nearly 8%, virtually all of which is due to the abolition of the large output subsidies on fertilisers. In Indonesia, the effect of eliminating fertiliser output subsidies is also important due to high subsidies on fertilisers in the reference scenario (68%), but dampened by the positive cross-country income effect of removing Indian fertiliser support. Similarly, in China, the elimination of input-related area payments contributes substantially (-0.8%) to the negative income effect of –1.1%. In almost all other countries, the negative income effect is primarily driven by the abolition of the biofuel mandates. These effects are the highest in the United States, where income declines by more than 5%, followed by Brazil, Canada, and the EU, where incomes decline by 1.1%, 0.5%, 0.4% respectively. In these countries the abolition of input and output fertiliser subsidies contributes positively to the total income effects. This is caused by the abolition of fertiliser policies in China, India, Indonesia, and the Russian Federation which results in higher prices of primary agricultural commodities. Within these four countries, commodity prices rise even more strongly than elsewhere, resulting in higher imports and lower exports when compared to the reference situation with fertiliser support. In Argentina, the positive income effect from the global abolition of fertiliser subsidies outweighs the negative effect of removing biofuel support.

Relative importance of simulated fertiliser and biofuel policies

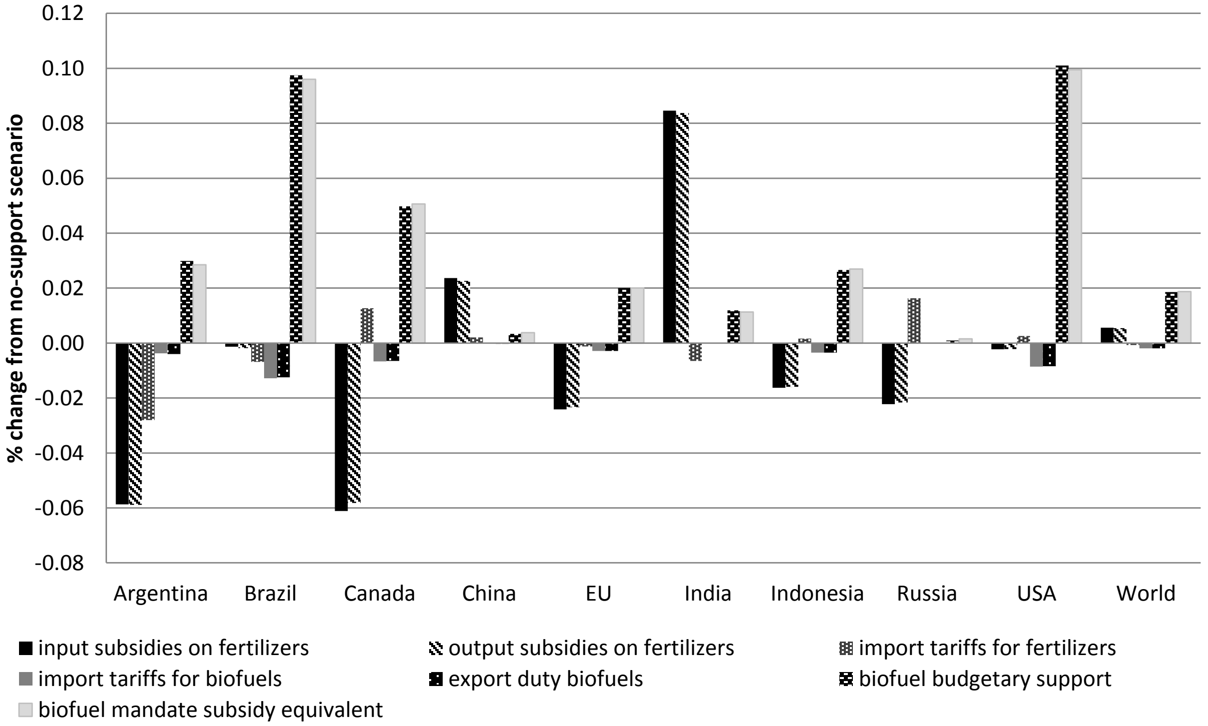
The impacts of the policies removed in the main counterfactual scenarios depend on the initial level of those policies. For example, the results discussed above suggest that removing import tariffs on fertilisers and biofuels would affect agricultural markets only a little, whereas a removal of fertiliser input and output subsidies would have more significant effects on agricultural markets. This finding is, however, related to two separate factors: on the one hand, initial import tariffs tend to be relatively low while fertiliser subsides in several countries are quite high. On the other hand, different types of support policies may have different effects on markets and incomes *per se*.

To allow a more rigorous comparison of the relative importance of the different policy measures, a multilateral introduction of a 1% *ad valorem* import tariff for fertilisers and biofuels and an introduction of a 1% fertiliser input and output subsidy was simulated and compared to a no-support simulation. Biofuel mandates are quantitative measures, but correspond to an equivalent subsidy to biofuel use that allows filling the mandate. A 1% introduction of this subsidy equivalent was also simulated. This allows for an identification of the marginal effects of the different policy measures. This section illustrates the consequences of these different policy measures on agricultural labour and capital income. Multipliers show the effects on global farm incomes (capital and labour) in USD per USD of global value of given support measures, as calculated from these *marginal* policy simulations.

The marginal introduction of fertiliser subsidies has the strongest positive income effects in India, where fertilisers represent a particularly high share in crop production costs. A marginal increase in subsidies leads to lower agricultural prices compared to countries with lower fertiliser cost shares. As a consequence, competitiveness and market shares of Indian agriculture increase in domestic and foreign markets. In contrast, countries with lower fertiliser cost shares see agricultural incomes fall due to lower market shares and lower crop prices. Model results suggest that fertiliser output subsidies on the one hand, and fertiliser input subsidies on the other hand, have very similar relative effects on world market prices and the production of primary agricultural products, and hence on agricultural incomes. This effect is partly due to the fact that the farming sector is the only user of fertilisers, and by the assumption of perfect competition in agriculture (zero-profit condition for firms). Support for biofuels – whether in the form of mandates or as budgetary support – in contrast raises agricultural incomes in all countries, as it increases demand for feedstock products and hence output prices.

Global agricultural income, as measured by the value added of labour and capital at opportunity cost, is found to be affected by marginal changes in fertiliser input subsidies and in biofuel mandates. However, biofuel policies show a stronger effect on agricultural income at global level compared with fertiliser policies. This is because in regions with relatively higher value added of agricultural labour and capital (such as the EU, Canada and United States) the simulated biofuel mandates have particularly strong effects on the demand for agricultural production with a positive price effect for agricultural production processed to biofuels (Figure 17).

Figure 17. Impacts on agricultural income, marginal policy, 2025



Note: Agricultural incomes are measured as factor value added of labour and capital. Results show the % change in agricultural incomes induced by each policy measure equivalent to 1%, as explained in the text.

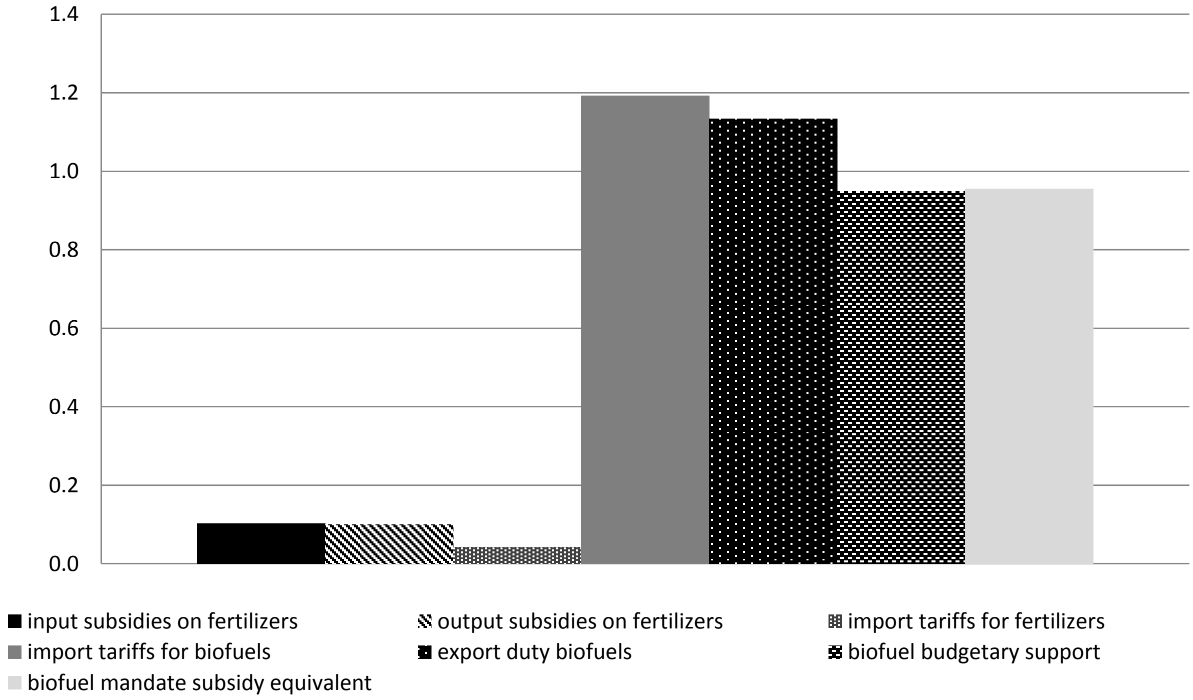
Source: MAGNET simulation results.

The derived multipliers of a marginal introduction of six different policies are presented in Figure 18. With multipliers at around 1.0, marginal changes in biofuel policies seem to be greater impacts on global farm incomes than fertiliser policies. This is consistent with the earlier finding that biofuel support tends to increase crop prices – and hence farm incomes – in all countries, whereas income benefits in countries providing fertiliser subsidies are partly offset by losses in other countries. Multipliers for individual countries can be significantly higher than 1 (such as in the cases of Brazil or China for biofuel budgetary support), reflecting significant trans-border impacts of these policies: such high multiplier values do not indicate net gains, but reflect impacts on national farm incomes from policies in other countries.

Global multiplier values for fertiliser polices are close to zero. In most countries fertiliser support policies leads to a significant increase in public spending with only little positive effect on agricultural income. However, for some countries like India and China, with high cost shares of fertiliser in agricultural production, these fertiliser support policies do show positive impacts on agricultural incomes, with multiplier levels of about 0.5.

Higher global multiplier for biofuel policies than for fertilisers can be explained by the strong price effects of these policies. Biofuel policies are directly affecting the demand side of agricultural markets. Given generally low elasticities in food demand, this has relatively strong impacts on agricultural market prices. Biofuel policies do not create net economic gains: on the contrary, some of the income benefits for farmers are financed by food consumers (and other users of agricultural output) paying higher prices. Fertiliser policies, on the other side, work on the supply side lowering agricultural production costs and as consequences also agricultural output prices and prices of other inputs.[32]

Figure 18. Global multipliers of marginal policy changes, 2025



Note: values show the increase in global farm incomes (capital and labour) in USD per USD of global value of given support measures.

Source: Calculated from MAGNET simulation results.

The importance of energy prices and market imperfections for policy implications

The previous sections discussed the implications of a hypothetical removal of fertiliser and biofuel support policies on agricultural markets and incomes, thus highlighting the impact of these policies for farming and farm incomes across countries. As noted above, this analysis was based on specific assumptions about the context in which these policies operate. Two of these contextual assumptions are of particular relevance to the production and use of fertilisers and of biofuels. On the one hand, the

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[32] Note the high multipliers calculated for import tariffs and export duties for biofuels. These are resulting from the fact that the value of trade measures is calculated taking into account the trade volumes only which are relatively small compared to production and use.

price of energy, particularly of natural gas, directly affects production costs of nitrogen fertilisers as well as the relative competitiveness of producing and using biofuels. On the other hand, the extent to which markets for phosphorous and potassium might be affected by imperfect competition may have consequences particularly for the effects of fertiliser policies. This section analyses how the results presented so far are affected by alternative assumptions about these two factors.

Sensitivity with respect to energy prices

As above, the discussion focuses on results for 2025 which are compared with a reference scenario based on the same assumptions for energy prices, unless otherwise noted. However, the discussion remains focussed on the total effect, without decomposing the fertiliser and biofuel policies.

Figure 19 shows the share of biofuels in total transport fuel use in the sensitivity runs (modified reference and counterfactual scenarios). The modified reference scenario assumes that biofuel mandates are binding in all countries apart from Brazil, and that the EU blending target of 7% will be met. In Brazil, the share of biofuels in total transport fuel use is projected to be 12%, which is significantly lower than the results presented above (32%).[33] Compared with the non-modified reference scenario, the mandatory biofuel shares have a higher ad valorem equivalent subsidy (about 1.5 percentage points higher in each of the countries with biofuel mandates).[34] This implies that abolishing the assumed biofuel policies should intensify the results described above on agricultural production and prices, and, as a result, income in all affected countries apart from Brazil.

Abolishing the simulated policies in a low-energy-price environment indeed results in a substantially stronger reduction in biofuel use and lower shares of biofuels in total transport fuel use, as users substitute towards relatively cheaper energy sources. These shares would now fall to 0.5% in Canada, 0.8% in the EU, 1.3% in India, 0.2% in Indonesia, and 1.0% in the United States, compared with 1.4%, 2.5%, 4.7%, 0.9% and 2.9% shown above for the higher-energy-price setting, shown again in the shaded areas of Figure 19 for easier reference. As the mandates are found to be binding at both energy price levels, the policy impact is hence substantially larger with lower energy prices, which is consistent with expectations. Speaking more generally, the impact of biofuel policies strongly depends on the level of economic competitiveness of biofuels relative to their fossil counterparts — which not only is a function of energy prices, but also changes with prices for agricultural feedstock commodities as well as technological improvements. While Brazil’s biofuel share would be much lower at lower energy prices, it is practically unaffected by an elimination of support policies as competitiveness is maintained also in such an environment.

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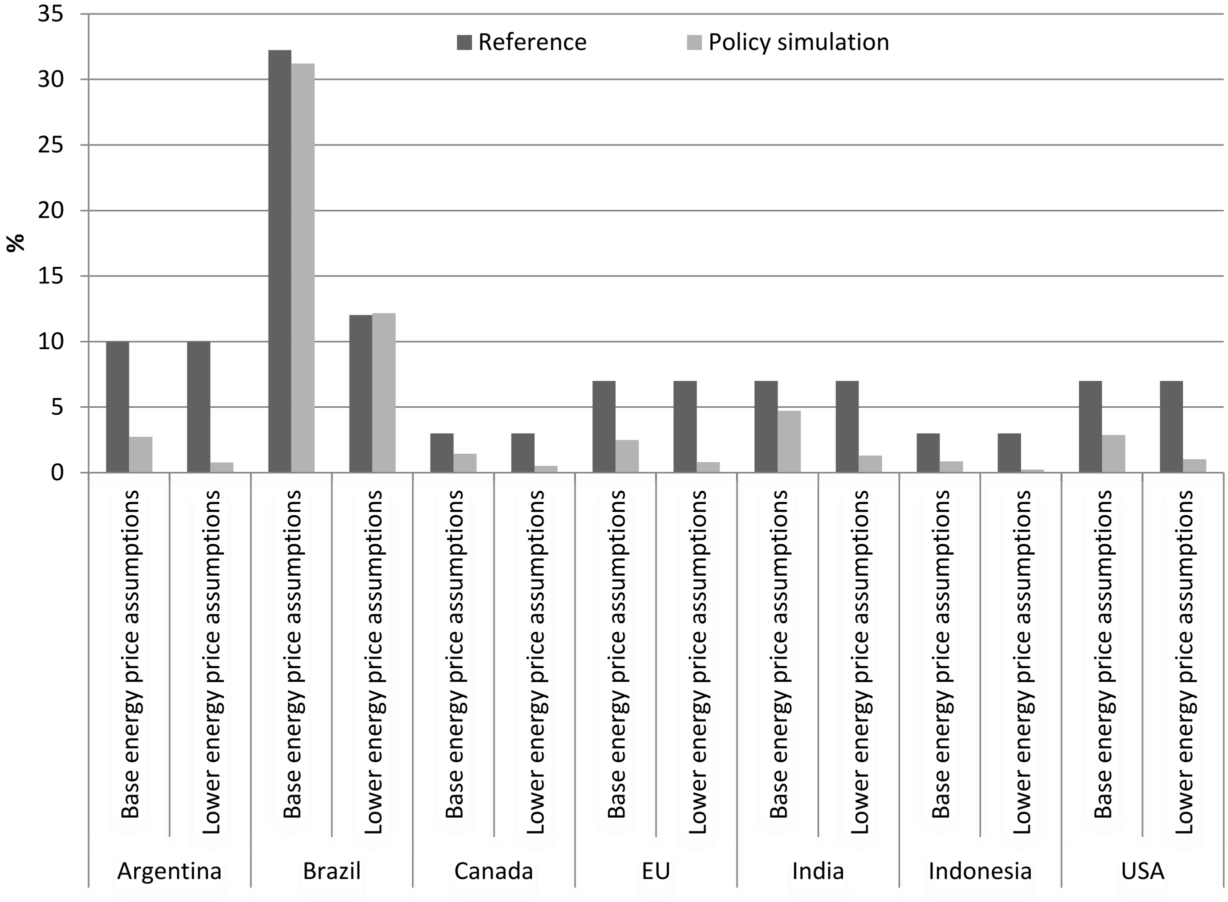
[33] Since July 1, 2007 the mandatory blending rate of anhydrous ethanol in gasoline fuel is 24%. As this covers less than 50% of transport fuels, it translates to a biofuel share of around 12%.

[34] Lower energy prices imply cheaper fossil fuels worldwide. Hence, the wedge between the production costs of biofuels and those of fossil fuels – corrected for differences in energy content – increases by about 1.5 percentage points and suggests a higher ad valorem subsidy on biofuel consumption.

Figure 19. Shares of biofuels in total transport fuel use, sensitivity to energy prices, 2025



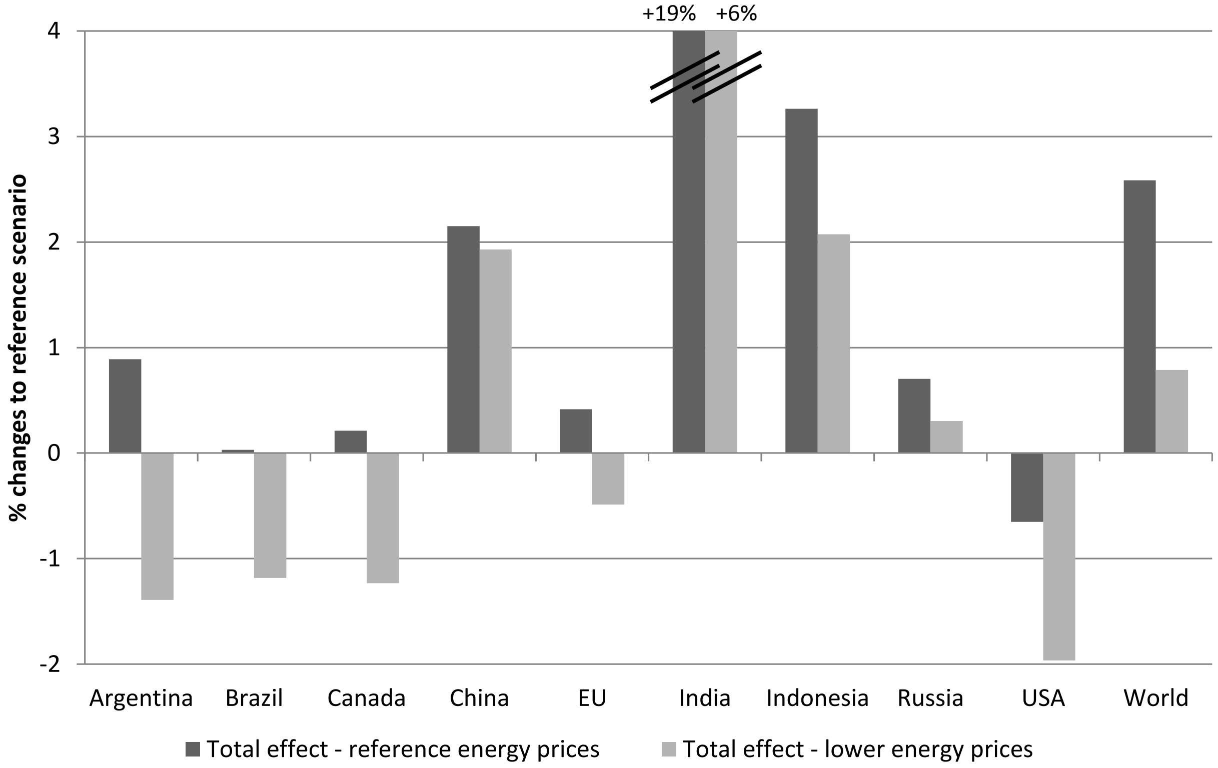
Note: the "Policy simulation" bars refer to the removal of all biofuel and fertiliser policies analysed.

Source: MAGNET simulation results.

As a consequence of the more significantly reduced demand for biofuels, the production of biofuels also decreases more significantly when biofuel mandates are abolished. The effects of low energy prices are most visible in Brazil. In Brazil, biofuel production decreases by about 30%, while in the original results the production decreased by 20%. The strong reduction in Brazil's biofuel production is related to falling exports – while domestic use, as discussed above, remains largely unchanged. In all other countries, the production decreases more sharply in a low-energy-price setting as well (by over -80%), but the differences to the original results are less visible as in either setting the remaining biofuel production would be small compared with the reference scenario with support.

More substantial reductions in biofuel production across countries imply more significant declines in demand for the crops used as feedstock for ethanol and biodiesel, and consequently larger price reductions. Figure 20 shows the impacts of the policy shocks on agricultural prices in the two alternative energy price cases. It repeats the results shown in Figure 14 and compares them with the price change from policy reform in a low-energy-price environment. In the latter case, the elimination of fertiliser and biofuel policies tends to have a more negative (or a less positive) effect on prices, and while the sign of the price effect still depends on the region as discussed above, it turns negative for a number of countries. These results show that in a lower-energy-price environment abolishing fertiliser subsidies (both input and output) affects agricultural prices relatively less than in a high-energy price world. The opposite is found for biofuel mandates: they have substantially bigger effects on agricultural markets when energy prices are low.

Figure 20. Impacts on agricultural prices, counterfactual and sensitivity scenario on energy prices, 2025

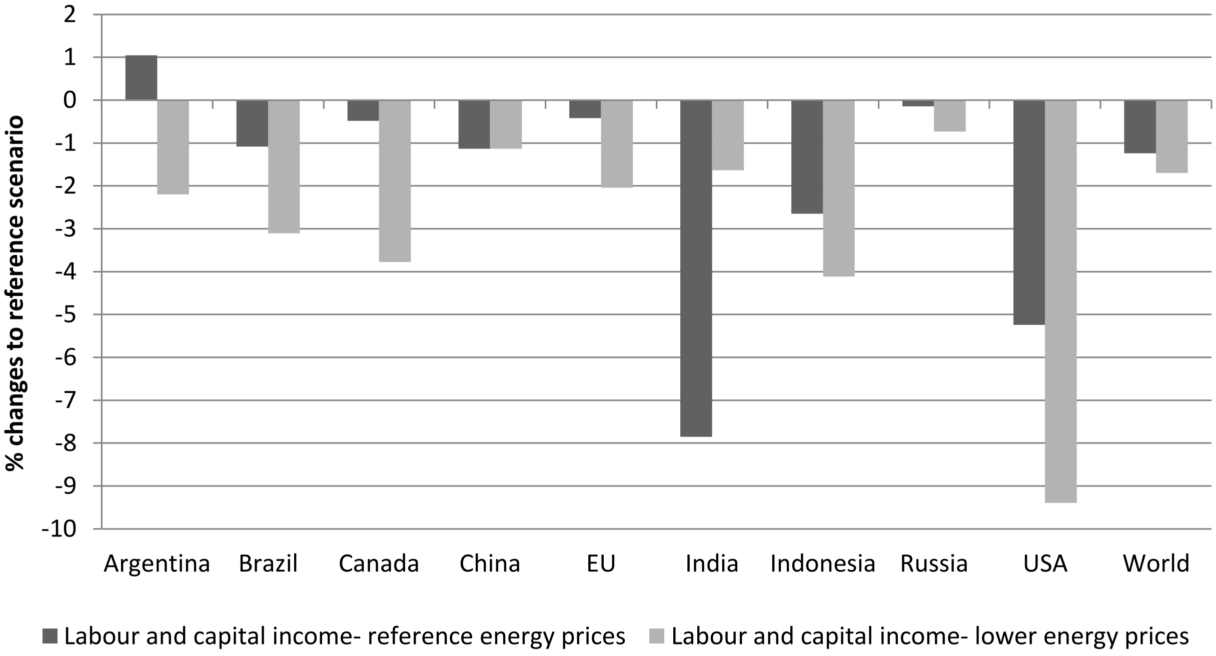


Note: the total effect-reference energy prices bar compares the results of the main counterfactual scenario with the reference scenario. The total effect-low energy prices bar compares the results of the counterfactual case with lower energy prices with a reference run assuming lower energy prices.

Source: MAGNET simulation results.

Finally, and as a consequence of the price and quantity changes, the elimination of fertiliser and biofuel policies reduces agricultural income to a greater extent when energy prices are low. This is shown in Figure 21, which again shows the income effects in the reference scenario (Figure 17) compared to those in a lower-energy-price environment. At the world level, labour and capital factor income of primary agricultural sectors would decrease by 1.7% if fertiliser and biofuel support policies were abolished in a low-energy-price environment, compared with 1.2% with the higher energy prices assumed for the reference case. At a regional level, the income effect is again most significant in the United States (-9.4% compared with -5.2% at higher energy prices).

Figure 21. Impacts on agricultural income, sensitivity scenario on energy prices, 2025



Note: Bars show the impacts of a removal of both fertiliser and biofuel support policies on agricultural incomes measured as factor value added of labour and capital.

Source: MAGNET simulation results.

Imperfect competition in fertiliser markets

The preceding sections discussed the removal of policies under perfect competition. As stated before, however, a certain degree of imperfect competition could be assumed in fertiliser markets given its high degree of concentration.[35] In this section we study whether the impact of abolition of fertiliser polices on production costs differs when there is imperfect competition. There is a difference between nitrogen on the one hand, and phosphorous and potassium on the other hand. The market for nitrogen is assumed to approach perfect market conditions, whereas a degree of market imperfection could be expected in phosphorous and potassium markets. This implies that only one third of the fertiliser market might be characterised by imperfect competition as nitrogen covers two-thirds of the market.

We provide only illustrative simulations as the degree of market imperfection in the fertiliser industry is not known. Given that the economic model used in this study by construction assumes perfect competition in all markets, the implications of some potentially imperfect competition in fertiliser markets is approximated by the introduction of a mark-up fertiliser producers charge over fertiliser production costs. According to Francois (1998), this mark-up is a function of the number of producing firms and the price elasticity of demand for the product in question. Empirical information is scarce, but

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[35] As noted earlier, this report makes no attempt to analyse whether, and to what degree, competition in fertiliser markets is indeed imperfect. Instead, it merely illustrates some of the potential consequences such imperfect competition could have for policy impacts.

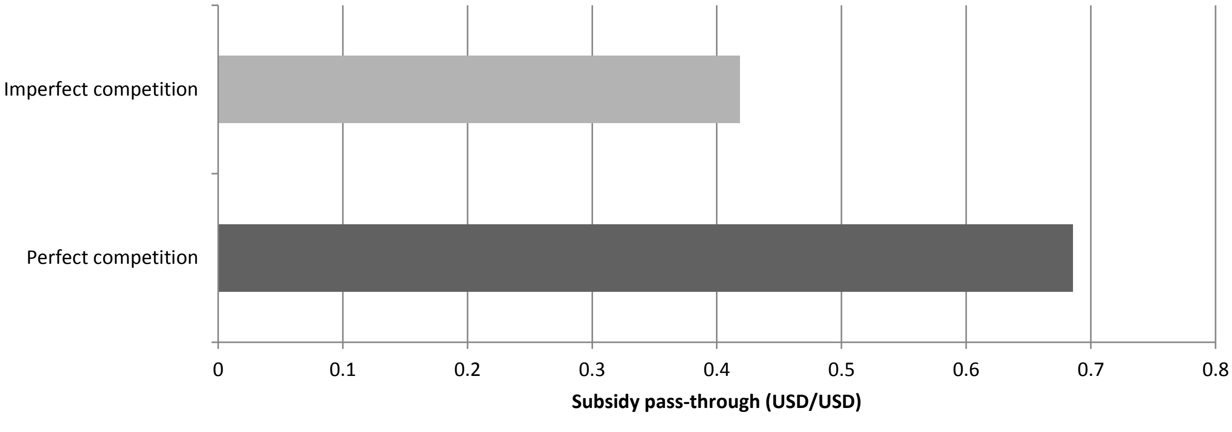
the simulated demand elasticity for fertilisers in MAGNET is found to be –0.4. To provide an idea of the potential implications of imperfect competition, a mark-up for phosphorous and potassium fertilisers is introduced that would double the fertiliser price relative to production costs – equivalent to a number of producing firms of five given the above demand elasticity.

Given imperfect competition, farmers are expected to face higher fertiliser prices than in the case of perfect competition, and to respond with lower production and use of fertilisers. In addition, any subsidy to fertilisers will partly be absorbed by the mark-up. The implications imperfect competition might have on the effects of fertiliser subsidies are therefore analysed by looking at the farm sector's costs for intermediary inputs and how these change due to the introduction of a small (1%) subsidy either to farmers (input subsidy) or to fertiliser producers (output subsidy). In the case of imperfect competition, a dollar of subsidies in the fertiliser sector can be expected to have a less pronounced effect on reducing these input costs than in a perfect competition situation.

Simulation results confirm this expectation. The model output suggests that, under perfect competition, each dollar of fertiliser subsidies results in slightly less than 0.7 dollars of reduction in the input costs faced by farmers (Figure 22). This value is lower than one as farmers increase their input use due to the reduced fertiliser prices and as larger fertiliser quantities incur increasing production costs for this input.

If fertiliser markets are characterized by imperfect competition, leading to a 100% mark-up between fertiliser production costs and fertiliser prices, the pass-through of subsidies is substantially reduced. In this case, a dollar of input subsidies would result in a cost reduction for farm inputs of only 0.42 dollars (Figure 22).

Figure 22. Global pass-through from a marginal change in fertiliser subsidies to the reduction of intermediary input costs of primary agriculture under perfect and imperfect competition



Source: MAGNET simulation results.

These results suggest that in case of imperfect competition the primary agricultural sector benefits less from fertiliser subsidies than in case of perfect competition. This is partly caused by the fact that relative to the fertiliser price, a given subsidy value is smaller under imperfect competition as the price includes the producers' mark-up and is hence higher than under perfect competition.

Note again that the results discussed here are based on a hypothetical assumption of market power. As explained above, while high degree of concentration in mineral resources notably for phosphorous and potassium can be seen as conducive to oligopolistic behaviour in the market, it is not sufficient for assuming that such oligopolistic behaviour is actually exercised. Despite regional concentration of supply, competitive behaviour is therefore perfectly possible, and more work is required to analyse whether, and if so to what degree, fertiliser markets are characterized by market power and oligopolistic behaviour.

It should also be noted that, as discussed above, the analysis of policy implications under imperfect competition is performed here in a stylized manner. As previously stated, it is unclear whether fertiliser markets are imperfectly competitive at all, and if so, to what degree. Consequently, a number of relevant parameters remain unknown. In addition, the model does not allow for a fully endogenous estimation of a price mark-up that a potentially oligopolistic supplier might be able to charge. The results shown here therefore have to be interpreted as indicative and rough estimates.

5. Summary of findings

Agricultural production and markets are linked to upstream and downstream sectors through important links. Analysing policy implications for agricultural markets and incomes therefore needs to go beyond agricultural policies alone. The present report has looked at policies within the sectors of fertilisers and biofuels, key markets within the agricultural supply chain.

Information about policies in these two sectors 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 fertiliser sector have been identified in four countries, mainly provided more or less directly to farmers to offset high fertiliser costs (Indonesia, the Russian Federation and China), but also given to fertiliser producers to counter high production costs, particularly in the context of high energy prices (India). These subsidies represent 12.5% of fertiliser and land costs in China, and range from 28% of fertiliser production costs in the Russian Federation to 68% in Indonesia. In contrast, import measures play only a minor role in relative terms.

Various forms of biofuel support policies are identified in the database. Support to biofuel use, mainly in the form of tax rebates or exemptions, are most widely spread across the countries covered by the database, but 23 of the 34 countries also apply biofuel mandates, requiring a minimum quantity or share of biofuels to be used in the transport fuel mix. Other forms of support, such as output-based payments or subsidies for the handling and storage of biofuels, play a comparatively smaller role across countries.

The computable general equilibrium model MAGNET was upgraded to better represent markets and policies in the fertiliser and biofuel sectors. 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 several counterfactual scenarios towards 2025 allowing the generation of implied policy impacts on agricultural markets and incomes in a forward-looking manner.

As suggested by economic reasoning, fertiliser and biofuel support policies result in lower fertiliser costs for crop farmers, higher demand for agricultural products used in biofuel production, and hence increased agricultural production. These effects are particularly pronounced for commodities used as biofuel feedstocks (e.g. grains, oilseeds and sugar crops) and differ across countries depending on their production structure and policy setting. Overall, global crop production is found to be up to 7% lower in the absence of fertiliser and biofuel support than under reference assumptions that include the current policies in place.

Average prices change relatively little if fertiliser and biofuel support policies were eliminated. Overall higher production costs would be offset by lower agricultural demand. Biofuel feedstock crop prices would fall by up to 2% (oilseeds) if biofuel policies were abolished, whereas an elimination of fertiliser support policies would increase crop prices by up to 6% (sugar crops, paddy rice). On average, prices of livestock products are only modestly affected by changes in fertiliser and biofuel policies, but regional effects depend on the share of biofuel by-products (DDGS and oilseed meals) in the feed mix and the amount of fertiliser support provided.

Agricultural income is found to be increased most notably in those countries currently providing support in fertiliser and biofuel markets, and removing this support leads to corresponding income declines. The income effect is most pronounced in India, where subsidies offset more than half of fertiliser production costs, and the US, where the policy-induced demand from biofuel production weighs strongly. Globally, fertiliser and biofuel support is found to raise agricultural incomes by about 1%, with the bulk of the income effect being related to biofuel mandates.

The globally much larger role of biofuel support for agricultural incomes compared to fertiliser subsidies is not only due to the amount of subsidies provided to biofuel markets (implicit in the case of mandates). Considering the marginal effects of fertiliser and biofuel support, each USD spent on biofuel support raises global farm incomes by more than USD 0.9, whereas one USD spent on fertiliser subsidies increases global agricultural incomes by just USD 0.05. While biofuel support generally benefits crop farmers in all countries, subsidies for fertilisers reduce international prices for crops and hence incomes in countries other than those providing the support.

These results are dependent on a number of assumptions made in this analysis. In particular, lower energy prices are found to significantly increase the income effects of the support policies analysed. At the same time, however, one can argue that lower energy prices reduce the case for fertiliser support which often is based on the high energy costs for producing this important farm input. Furthermore, a stylised sensitivity analysis shows that input costs for farmers are affected to a much lesser extent in the presence of market power than under perfect competition. More empirical research is required to better understand whether, and to what degree, markets for phosphorous and potassium might indeed be characterised by imperfect competition, given the relative concentration of natural reserves of these mined products.

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.

It is also important to note that a number of factors potentially relevant for the policy implications discussed here are not or not fully represented in the model, such as biofuels other than those from grains, sugar crops and vegetable oils, sustainability criteria attached to biofuel support policies, fertilisers other than N, P and K, and regulatory measures affecting the production, transport and use of fertilisers. The empirical basis for some of the model parameters, in particular with respect to the newly introduced fertiliser markets, is weak. In consequence, many of the results shown in this report should be seen as indicative, and used with the necessary degree of care.

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Annex 1

Technical Description of Magnet

General characteristics of MAGNET

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 et al., 2013). It is built upon the GTAP model (Hertel, 1997) and is the successor of the LEITAP model which has been used several times for policy analysis (see for example Banse et al., 2008; van Meijl et al., 2006; Nowicki et al., 2009, Woltjer, 2011). The output of the MAGNET model is published in many journal articles. Recently work on yields is published in Renewable and Sustainable Energy Reviews (Powell and Rutten, 2013). MAGNET is one of the nine global models selected in the OECD\AgMIP model inter-comparison project and output of this research is published in PNAS (Nelson et al. 2013) and six articles in Agricultural Economics (including in particular von Lampe et al. (2014) and Robinson et al. (2014).

MAGNET adopts a modular approach, whereby the standard GTAP-based core is augmented with modules depending on the purpose of the study. MAGNET contains some institutional innovations and is supported by various tools like a tool that structures the code (GTREE), a tool to automatize, structure and document data procedures (DSS), a tool to run and analyse scenarios and a strategy to structure mappings, separating modules, and administrating changes. Its philosophy is in line with GTAP, namely low entry barriers for CGE analysis, whereas its modular set up facilitates working in (cross-institutional) modelling teams and allows to build in dedicated modules linking it with other models (for example the IMAGE model). Currently the system is used at LEI-WUR, JRC-IPTS and TI (previously known as vTI).

The core of the MAGNET database is the GTAP database. MAGNET uses a series of additional databases, such as GTAP satellite databases, FAOSTAT (commodity balances, land use, land cover and fertiliser), data on biofuels from the International Energy Agency, land use parameters taken from the IMAGE model. Processing of data is coded so as to make update of the original source data easier, to track how data are processed and to maintain flexibility using different GTAP database versions. Possible adjustments of the data which MAGNET can undertake involve disaggregating regions and sectors, rebalancing the SAM, and adding data on land use, land cover, greenhouse gasses, employment or international capital flows. Having these procedures in place allows introducing first generation biofuels (ethanol and biodiesel), DDGS (a by-product from grain-based ethanol production, used as animal feed) and splitting several GTAP sectors to include a sector that only makes crude vegetable oil with oilcake as a by-product, the three fertiliser sectors studied in this report, an animal feed sector, and splitting the sugar production in plain sugar and molasses. Additional bilateral trade data are taken over from BACI[36] whereas data on import tariffs for the new sectors are taken from MacMaps. All data are processed starting from the aggregation level at which they are supplied, and are aggregated or disaggregated using mappings towards the lowest aggregation level that MAGNET uses. This implies that for example tariff data is considered at the HS6 digit level and aggregated (weighted averages) according to the chosen commodity aggregation scheme for a particular study.

Starting point of MAGNET is the GTAP model (Hertel, 1997). GTAP assumes perfect competition, namely producers are price takers whereas in order to produce output they choose the cheapest combination of imperfectly substitutable labour, capital, land, natural resources and intermediates. Input and output prices are endogenously determined by the markets so as to achieve supply and demand equilibrium. Factor markets are competitive between sectors but not between regions. Households are assumed to distribute income across savings and (government and private) consumption expenditures according to fixed budget shares. Consumption expenditures are allocated across commodities according to a non-homothetic CDE expenditure function. Land, labour, capital and natural resources (primary production factors) are fully employed in each region and the aggregated supply of each factor equals its demand (equilibrium). Furthermore, GTAP assumes imperfect competition between domestic and imported commodities (Armington assumption).

MAGNET allows for easy extension of the GTAP model through modules. Examples are improved treatment of the agricultural sector through, for example, various imperfectly substitutable types of land, an improved land use allocation structure, an endogenous land supply function and the possibility of substitution between various animal feed components, agricultural policies such as production quotas and first and second pillar Common Agricultural Policies. On the consumption side, a dynamic CDE expenditure function was implemented that allows for changes in income elasticities when purchasing power parity (PPP)-corrected real GDP per capita changes. In the area of factor markets modelling, the segmentation and imperfect mobility between agricultural and non-agricultural labour and capital was introduced in a dynamic way. All types of CES production trees can be made by changing a simple table, allowing adjusting them depending on the application of the model. Last but not least, MAGNET is extended with a dedicated module on the EU Common Agricultural Policy and with a dedicate module on biofuel policies. On the international capital side a dynamic module for international investment has been implemented. Potentially other modules can be implemented, like a module on imperfect competition.

Specific features of MAGNET important for the analysis of agricultural markets[37]

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

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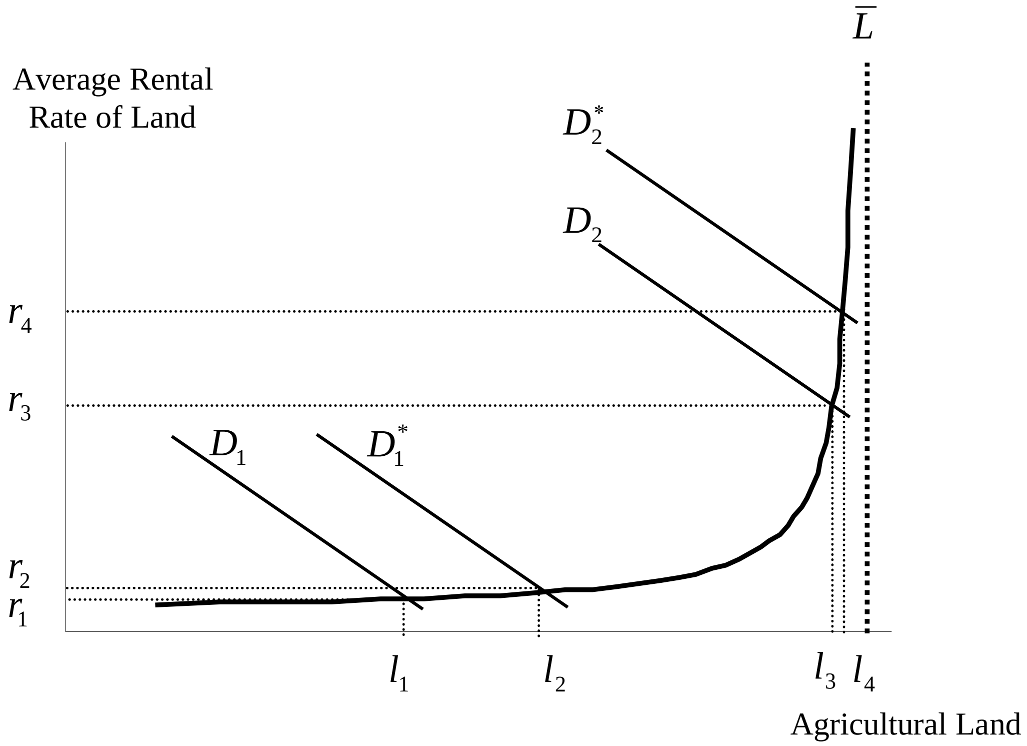
[36] "Base pour l'Analyse du Commerce International" (CEPII, 2013).

[37] A more extensive documentation of the MAGNET model can be found in Woltjer et al. (2013).

agricultural land, converting non-agricultural land to agriculture, converting agricultural land to urban use, and agricultural land abandonment.

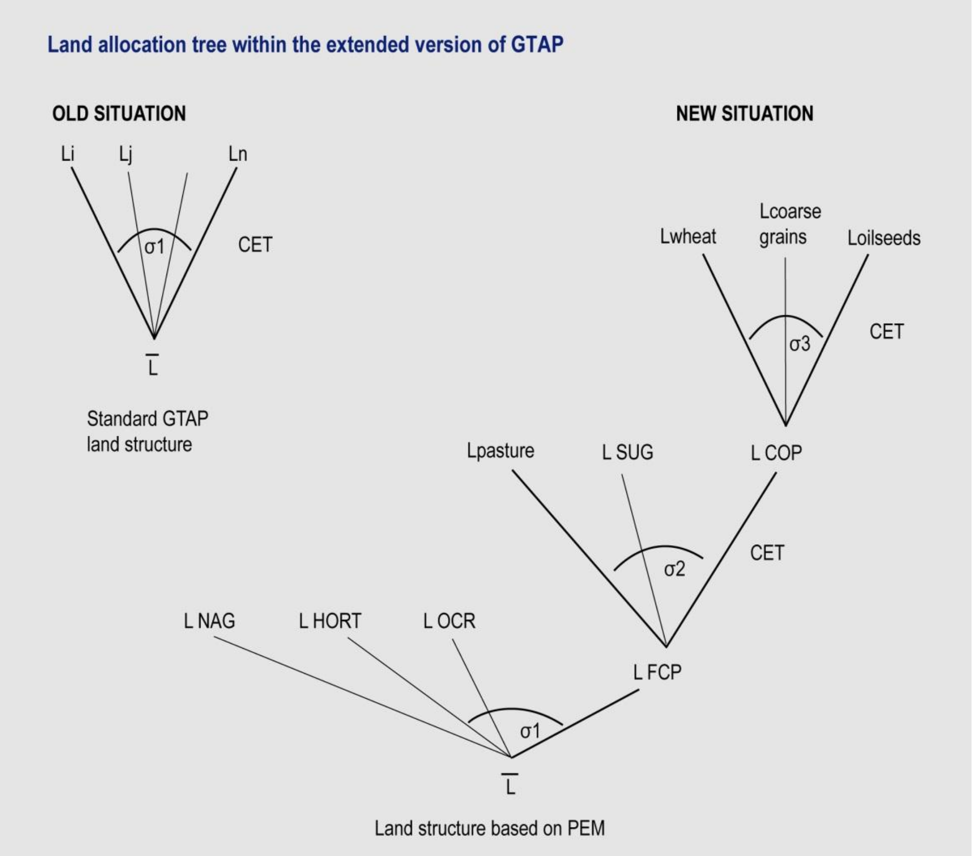
Figure A.1 gives the general idea behind the land supply curve. When agricultural land use approaches potential land use ($\overline{L}$), farmers are forced to use less productive land with higher production costs (strongly increasing part of the supply curve). As a consequence, in land-abundant regions 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 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^*). These land price differences will influence competitiveness of biofuel production. The key problem is the empirical implementation of this land supply curve for all major regions in the world, as land price data are not available on a global scale. Eickhout et al. (2007) used biophysical data, such as spatially varying land productivity, from the IMAGE model to approximate the supply curve. For the EU15 countries, more information on land prices is available, and empirical estimates have been used here (Cixous, 2006).

Figure A.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 biofuels and fertilisers, the functioning of the land market is particularly crucial. Birur et al. (2007) used agro-ecological zones in combination with an exogenous land supply, following the methodology outlined in Lee et al. (2005). We propose 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 A.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 A.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).

Segmented factor markets: Perfect capital and labour mobility between agricultural and non-agricultural sectors, as assumed in the standard GTAP, implies equal remuneration for these production factors. This is not supported by empirical evidence (De Janvry et al., 1991). In MAGNET factor markets are divided into agricultural and non-agricultural labour and capital. By doing so MAGNET accounts for differences in wages and returns to assets between the agricultural and the non-agricultural sector taking into account that these are larger in the short term than in the long term. Therefore, capital and labour market segmentation is introduced by specifying a CET structure (Keeney and Hertel, 2005). The elasticities of transformation have been calibrated to fit estimates of the elasticity of labour supply from PEM (OECD, 2003).

A flexible CES tree production structure: All types of CES trees can be easily implemented. At this moment most sectors have the possibility to substitute between different production factors and between capital and energy. The petroleum sector has the possibility to substitute between ethanol, biodiesel and fossil fuels. The animal feed sector can substitute between (grass) land and animal feed from crops, and within animal feed from crops between different types of animal feed, including relevant by-products that change with biofuel production like DDGS, oilcake and molasses. The agricultural sectors can also substitute between land and fertiliser, while the ethanol sector can substitute between different feedstocks. 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). Furthermore, we use a one-level nested CES structure to account for substitution among ethanol feedstocks. The blending sector and the fertiliser **composite** are explained below.

Biofuels: A specific biofuel module has been developed that allows the representation of first-generation biofuels for transport and their respective support policies. More details on this module can be found further below.

Linkage between crop and livestock sectors: Livestock sectors are linked in various ways to the crop sectors. First, livestock sectors use crops (e.g. wheat, coarse grains, oilseeds, other crops) in their feed mix to raise the animals. In the feed mix agricultural crops compete with compound feed, oilcakes, molasses and by-products from biofuel production (DDGS). 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 (Figure A.2). The nested land structure implies that it is more difficult to convert pasture land into crop land and vice versa than to convert for example wheat in coarse grains land within the LCOP nest. There is no link in the model that allows using organic fertilisers (e.g. manure) from the animal sectors in the crop sectors.

Consumption: A dynamic CDE expenditure function is implemented that allows for changes in income elasticities when purchasing power parity (PPP)-corrected real GDP per capita changes (see Hertel (2007) for more details on the CDE function).

Regional and sectoral aggregation for the present analysis: Details on the regional aggregation used in the analysis for this report can be found in Table A.1, while information on the sectoral representation can be found in Table A.2.

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 (China), Mongolia and Chinese Taipei	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
United States	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, fertilisers and the animal feed sectors and are not covered explicitly as disaggregated commodities in the GTAP database.

Biofuels in MAGNET

MAGNET has the possibility to apply all types of subsidies, quotas and tariffs that can be used routinely in a GTAP-type model. MAGNET’s dedicated module on biofuel policies involves the possibility to implement biofuel mandates in transport.

Although the GTAP database includes several transportation sectors these do not cover all fuel used for transportation. Firms, private households and the government purchase petroleum products which are partly used for transportation and partly for other uses like heating. In order to implement a biofuel policy the model needs to account for demand for petroleum products by the transport sectors as well as demand for petroleum products by households and government. Data on biofuel use in transport are calculated from the IEA database.

MAGNET includes first-generation ethanol and biodiesel as separate sectors. Biofuel consumption data for 2007 are taken from the *World Energy Outlook* (IEA, 2011). The model assumes that ethanol is produced from grains (wheat, coarse grains) and sugar beet or sugarcane, whereas biodiesel is assumed to be made entirely from crude vegetable oil. Furthermore, the model includes by-products of the biofuel processing activities, such as oilcakes (by-product of crushing oilseeds) and DDGS (a by-product of producing ethanol from grains). These by-products are used as intermediate inputs in livestock production.

Biofuel blending mandates

One of the most important policy instruments used in the biofuel sector is the implementation of **blending mandates.** Blending mandates are specific instruments for volume-based policies. In contrast to many other policies measures such as the the milk quota, they do not stipulate the quantity supplied but the quantity demanded. However, blending mandates may affect the entire supply chain. While farmers would increase the production of, for example, rapeseed, oil mills will increase processing capacities. Additional investments will be made and additional labour forces will be employed. Thus, the growth of a whole economic sector relies on the blending mandates.

MAGNET captures changes in **biofuel mandates** by targeting biofuel shares in transport. Obligatory blending is modelled by introducing a biofuel share which can be targeted to implement the mandates. Furthermore, a subsidy on biofuel use is introduced to achieve the targeted blending rate. In this study, the subsidy on biofuel use is made budget-neutral by an offsetting tax related to total fuel consumption. The model assumes that the petroleum sector blends fossil gasoline and diesel with ethanol and biodiesel via a CES function. The nested CES structure implies that biofuel demand is determined by the relative prices of crude oil versus ethanol and biodiesel, inclusive of taxes and subsidies. In addition, and as part of the standard GTAP approach, other budgetary support to the production and use of biofuels are considered as well.

We developed the biofuel blending module based on earlier LEITAP biofuel work as described in, for example, Banse et al. (2008 and 2011). Specifically, we developed the code using an example of a mandate requiring a blending target for fuel used in transportation. For meaningful biofuel analyses we included also other MAGNET modules in the model. Necessary is the flexible production structure to enable substitution between biomass based ethanol and biodiesel on the one hand, and crude oil based petrol and diesel on the other hand. Including the by-products from the production of biodiesel and ethanol, such as DDGS, molasses and oil cakes, is highly relevant for the analysis of biofuel support policies. As direct and indirect land use impacts are crucial it is fundamental to also include the land markets: endogenous land supply and allocation of land across sectors. Other characteristics of the agricultural sector are also important, such as the segmented mobile factor markets (as agricultural factor prices deviate from these prices in other sectors) and all agricultural policies.

With respect to production of ethanol (biogasoline) the CES production function allows for the substitution between different inputs like sugar cane, sugar beet, molasses, wheat, and maize. For biodiesel vegetable oil is used as an input. The production of ethanol allows for by-products like DDGS that can be used for animal feeding. For biodiesel vegetable oil is used, where the (crude) vegetable oil sector has oilcake as a by-product. The animal feed sector and the animal sectors themselves are able to substitute between different types of feed through a nested CES structure. In this manner also the indirect effects of biofuel production through its by-products is taken into account.

Biofuel data

A large amount of data was collected to be able to split off 1st generation biofuel from the chemical industry in the GTAP 8 database used in the MAGNET model. The main data sources that have been used when collecting the following datasets are Maung and Gustafson 2009; Mulugetta 2009; BBI 2010 and BioGrace 2011. Data on cost structure, conversion efficiency and production of co-products were mainly derived from these sources. A representative cost structure has been constructed for all regions. This cost structure differs across regions due to different crop and other intermediate prices. The resulting dataset is shown below. Data on biofuel production and use were taken from the database of the International Energy Agency (IEA, 2011). Data on feedstock composition are not available from a consistent source and therefore taken from various sources (e.g. Ecofys, 2011).

The transformation biofuel feedstock use and biofuel output is made based on energy content, using conversion factors to transform feedstock volumes (in kilograms) to biofuel energy (in gigajoules). The monetary value of feedstock commodities is determined based on the volume required by the biofuel sectors and the feedstock price, as provided by the FAO. The value of biofuels is determined based on both the cost of feedstocks and the cost of other production factors. In consequence, only monetary values are used within the MAGNET model, while physical volumes are used only in the calculation of the required value data.

Table A.3. Key assumptions behind biofuel production cost calculations (EUR/litre)

	bioethanol from sugar beet Europe	bioethanol from sugar cane Brazil	bioethanol from molasses Indonesia	bioethanol from wheat EU27	bioethanol from rye Germany	bioethanol from maize USA	biodiesel from palm oil Malaysia	biodiesel from rapeseed oil EU27	biodiesel from soybean oil USA	
Year	**2007**	**2007**	**2007**	**2007**	**2007**	**2007**	**2007**	**2007**	**2007**	**unit**
Key assumptions										
Lower Heating Value biofuel	26.81	26.81	26.810	26.810	26.810	26.810	37.200	37.200	37.200	MJLHV/kg
Density biofuel	0.79	0.79	0.794	0.794	0.794	0.794	0.890	0.890	0.890	t/m3
Conversion efficiency feedstock to biofuel	0.54	0.36	0.36	0.54	0.54	0.52	0.96	0.96	0.96	MJ/MJ
Conversion efficiency feedstock to biofuel	0.10	0.09	0.09	0.371	0.371	0.381	0.708	0.708	0.966	l/kg
Feedstock price	31	13	9	128	142	110	263	500	624	euro/t
Electricity processing feedstock to biofuel	0.05	0.00	0.00	0.08	0.08	0.08	0.00	0.00	0.00	MJ/MJ
Natural gas processing feedstock to biofuel	0.44	0.00	0.00	0.57	0.57	0.76	0.12	0.12	0.12	MJ/MJ
Electricity price	0.05	n/a	n/a	0.05	0.05	0.05	0.05	0.05	0.05	euro/kWh
Natural gas price	5.11	n/a	n/a	5.11	5.11	5.11	5.11	5.11	5.11	euro/GJ
Co-product 1	beet pulp	n/a	n/a	DDGS	DDGS	DDGS	glycerine	glycerine	glycerine	n/a
Co-product 1 production	26	n/a	n/a	999	999	1030	100	100	100	kg/t
Protein content co-product	10	n/a	n/a	31	31	31	n/a	n/a	n/a	%
Co-product 1 value	210	n/a	n/a	171	171	137	150	150	150	euro/t
Co-product 2	yeast&ferti	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Production costs										
Feedstock	0.31	0.15	0.10	0.34	0.38	0.29	0.37	0.65	0.94	euro/l
Other transport	0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.04	euro/l
Capital costs interest only	0.02	0.02	0.02	0.02	0.02	0.02	0.05	0.05	0.05	euro/l
Capital costs depreciation	0.02	0.02	0.00	0.01	0.01	0.01	0.03	0.03	0.03	euro/l
Gas	0.05	0.00	0.00	0.06	0.06	0.08	0.02	0.02	0.02	euro/l
Electricity	0.02	0.00	0.00	0.02	0.02	0.02	0.00	0.00	0.00	euro/l
Chemical rubber products	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	euro/l
Other processing costs exc. labour	0.05	0.04	0.03	0.05	0.05	0.05	0.02	0.02	0.02	euro/l
Labour	0.06	0.02	0.02	0.06	0.06	0.06	0.02	0.02	0.02	euro/l
Skilled	0.03	0.01	0.01	0.03	0.03	0.03	0.01	0.01	0.01	euro/l
Unskilled	0.03	0.01	0.01	0.03	0.03	0.03	0.01	0.01	0.01	euro/l
Co-product 1 value	-0.05	0.00	0.00	-0.14	-0.14	-0.11	-0.01	-0.01	-0.01	euro/l
Co-product 2 value	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	euro/l
TOTAL	**0.44**	**0.26**	**0.17**	**0.46**	**0.50**	**0.44**	**0.56**	**0.85**	**0.95**	**euro/l**

Source: Woltjer et al. (2013).

Data sources

Five types of data (sources) are used: IEA data, detailed cost data for the production of biofuels per feedstock, the share of feedstocks used for biofuel production in the different countries, FAO prices for biofuel feedstocks and gasoline prices. The IEA data describe the production and trade of biofuels per country. The share of the feedstock for every biofuel producing country describes which feedstock is used in each biofuel producing country. For most countries only one feedstock is used. For the EU more detailed data was available and a share of several feedstocks was used. The input cost data for biofuels to calculate production cost are structured in Table A.3.

FAO prices of the biofuel feedstocks (vegetable oil), are calculated in dollar per kg, and are either based on FAO quantities and GTAP values or FAO prices. Gasoline prices are in dollar per ton of oil equivalent (toe).

To explicitly include the biofuel data with their by-products in the database, several steps are needed: 1) First, the data for the input cost are read in and it is determined for each country how much biofuel is produced and which inputs are used to produce the biofuel;

2) In the next step the total inputs for biofuel are taken out of the original sectors and included in the newly created biofuel sector; 3) Then the trade in biofuels is included based on IEA data and the trade margins are adjusted consistent with the trade changes; 4) The supply needs to be adjusted to domestic production; 5) Total production of biofuels is added to the petroleum sector as an input. Subsidies for biofuel production are calculated based on the idea that the price of ethanol and biodiesel per MJ should be the same as the price of gasoline per MJ; 6) Total production of by-products is added to sector livestock; 7) Finally several standard adjustments are included to balance the SAM.

These data calculations imply that in 2007 prices for fossil fuels (gasoline and diesel) were below production costs for biofuels (ethanol and biodiesel, respectively) when accounting for the lower energy content in biofuels compared with their fossil substitutes. The difference between the production costs for ethanol and the gasoline prices are estimated at 4% for Brazil, 30% for both India and Indonesia, 40% for the United States and 50% for the EU. The production costs of biodiesel are almost 50% higher than fossil diesel prices in most countries. This suggests that the base year initial biofuel shares in total transport fuel use are driven mainly by mandates and other biofuel support policies whereas Brazilian ethanol was relatively competitive against fossil gasoline.

Fertilisers in MAGNET

In MAGNET the fertiliser sector has been disaggregated from the chemical. Fertiliser is used in the crops and livestock sectors as a substitute of land. This allows for intensification taking place based on land rent and agricultural prices.

With respect to policies, the model allows depicting of all types of quantity and price based policies that are relevant for the sector. Examples are subsidies or taxes on fertiliser use in each of the agricultural sub-sectors, tariffs and subsidies on fertiliser trade, and subsidies or taxes on production or inputs in the fertiliser sector.

For this study MAGNET is extended to explicitly account for the three macronutrients: nitrogen (N), phosphorus (P2O5) and potassium (K2O). Data on fertiliser use per crop and per country for 2007 are taken from Heffer (2009). Bilateral trade data for fertiliser products, extracted from the BACI database, are converted into the three macronutrients using conversion factors provided by IFA (2013a) (Figure A.4). Assuming that the three nutrients are used as intermediate inputs in the crop-producing sectors identified in Heffer (2009), we calculate the implied production volume. The three macronutrients enter MAGNET as separate sectors, which implies that the original chemical sector in the GTAP database is split into four sectors (nitrogen, phosphorus, potassium and rest of chemicals). The output value of fertilisers is derived using the following fob prices as reference prices: Urea (HS 31102.10) for nitrogen, DAP (HS 3105.30) for phosphorus, and MOP (HS 3104.20) for potassium (Figure A.5). Bilateral tariff data obtained from the 2007 MacMap database for Urea, DAP and MOP, serve as reference bilateral tariffs for nitrogen, phosphorus and potassium, respectively. The production technology for the three fertiliser sectors is derived from IFA (2013b). There are regional differences in the production technology of nitrogen in particular which are due to regional deviations in natural gas prices. The rest of chemicals sector is then calculated residually. Initial tax rates on primary factors and on firm’s domestic and imported purchases of the three macronutrients are based primarily on OECD (2013b) where given and assumed to be consistent with the original GTAP chemical sector for countries not covered in this database. Data adjustments in MAGNET are implemented in the model’s underlying Social Accounting Matrix (SAM). For the rest of the chemicals sector, taxes and subsidies are adjusted accordingly so that the SAM remains balanced. The model assumes that fertilisers can substitute for land in crop production, thereby accounting for extensification vs. intensification of agricultural production. The substitution elasticity between land and fertilisers is set at 1.25 and is taken over from GTAP-AGR. In contrast, the model assumes fixed proportions in the use of the different fertilisers N, P and K (i.e., a Leontief structure).

Sensitivity with respect to key model parameters

For biofuel market development, the elasticity of substitution between fossil fuels and feedstock in the petroleum industry is crucial, yet uncertain. Moreover, the development of international trade and, therefore, regional production and land use heavily depends on the value of the trade (Armington) elasticities. Banse et al. (2008) conducted sensitivity analyses with regard to these two parameters and found that the qualitative results are not fundamentally different, but the magnitude of the effects can change substantially.

As discussed above, fertilisers are modelled in fixed proportions between nitrogen, phosphorous and potassium and with a substitution elasticity between land and fertilisers taken from the GTAP-AGR database. Empirical evidence with regard to the value of the land-fertiliser substitution elasticity is scarce. This parameter may have, however, significant influence on some of the model results shown in this analysis. For example, a higher value of the substitution elasticity between land and fertilisers would generally result in more pronounced reductions of fertiliser use following an elimination of fertiliser input subsidies. This would result in lower yields and higher land use.

Macro and Sectoral Productivity Growth in MAGNET

Technological change is one of the key determinants of economic growth, global prices, production and trade. This section discusses the need to calibrate the paths for sectoral "factor embodied" technical change in CGE models residually in order to replicate the given GDP growth path (see, Robinson et al. 2014). Given the core FAO-OECD assumptions of exogenous GDP and population growth, total factor productivity (TFP) is calibrated within MAGNET residually so that the model achieves the targeted scenario GDP growth, given the growth generated by increases in production factors times their productivity. GDP growth in MAGNET can be attributed to growth in high and low skilled labour, capital, land and technical progress (TFP). The growth of land and capital is determined endogenously, while the growth of labour follows from projections of population growth, leaving TFP growth to be specified residually. Land-embodied technical change is equal to the sectoral exogenous yield shift factors (source).

With regard to factor-biased technical change, MAGNET assumes labour-augmenting or Harrod-neutral technical change, which yields the stylized fact of a long run constant capital-output ratio (Uzawa, 1961; Jones and Scrimgeour, 2008). Empirical results indicate that the assumption of uniform technical progress across sectors is generally not realistic. Studies indicate that TFP growth in developed countries is highest in agriculture, followed by manufacturing and services (Dollar and Wolff, 1993 and 1997; Kets and Lejour, 2003). MAGNET assumes different sectoral TFP developments which are based on estimates of CPB (Kets and Lejour, 2003). These estimates describe sectoral TFP developments in the OECD between 1970 and 1990. Based on the OECD International Sectoral Database, these estimates confirm the stylized fact that TFP growth is relatively high in agriculture and relatively low in services. Within manufacturing, TFP growth is higher for chemicals and capital goods and lower for food processing, paper and publishing and metals. TFP growth in services sectors (e.g. construction, financial services and other (government) services) is almost zero or even negative, while it is relatively high in transportation and communication. The relatively high growth in agriculture relatively to other sectors implies that real prices of agriculture have a downward pressure.

Table A.4. Assumptions about macroeconomic trends, 2007-2025

Country/region	GDP		Population	
	Annual % change	Total % change	Annual % change	Total % change
Argentina	3.6	89.1	0.8	15.3
Australia	3.0	69.4	1.3	25.8
Brazil	3.9	99.0	0.7	13.9
Canada	1.9	39.2	0.9	17.0
Chile	4.3	112.5	0.8	14.8
China, Hong Kong (China), Mongolia and Chinese Taipei	7.3	254.2	0.3	5.7
European Union (27 member states)	1.3	26.9	0.2	4.2
India	6.5	212.1	1.2	24.3
Indonesia	6.2	195.9	0.9	16.9
Japan and Korea	1.2	23.6	0.0	-0.6
Malaysia	4.6	123.4	1.5	30.1
Mexico	2.9	66.0	1.0	20.0
Morocco	4.8	130.4	0.9	17.8
Russia	2.9	66.7	-0.2	-3.0
South Africa	3.4	83.0	0.5	10.1
Turkey	3.8	95.6	1.0	20.0
United States	1.9	40.2	0.8	15.7
Rest of Africa	5.2	148.4	2.3	51.8
Rest of Asia	4.3	113.3	1.3	25.9
Rest of Central and South America	3.9	99.1	1.2	24.0
Rest of Europe	2.2	48.9	0.0	0.7
Rest of Oceania	2.1	45.8	1.6	32.9
World	2.9	66.8	1.0	20.2

Source: OECD/FAO (2013).

Yields

MAGNET, like any other CGE does not have yields as such, but it calculates production and land use which enables the yields to be calculated ex post. The nested CES production function determines the relation between land use (like any other production factor or intermediate input use) and production. The CES production function implies that with regard to land use we can distinguish between an expansion and a substitution effect. The expansion effect implies that you need more land when you expand production and does with constant returns to scale not influence the yields. The substitution effect implies that relative factor prices determine the substitution between production factors. If land prices rise relatively to labour and capital prices then land is substituted by labour and capital and the yield will go up. Yields are not only influenced by this substitution effect but also by an exogenous yield trend. The exogenous yield trend in this study is taken from PBL (2012) and presented in Table A.5.

Table A.5. Assumptions about exogenous yield trends, % p.a., 2010-2025

	Paddy rice	Wheat	Coarse grains	Oilseeds	Sugar beet & cane	Fruit & vegetables	Other crops	Pasture land
World	1.2	0.9	1.0	1.3	0.9	1.3	1.0	2.5
Argentina	0.9	1.2	0.8	0.8	0.6	1.0	0.5	2.4
Australia	0.4	1.0	1.6	1.1	0.8	1.3	0.7	2.3
Brazil	1.3	0.7	1.4	0.9	1.0	0.2	0.8	1.7
Canada	0.0	0.8	1.3	0.9	1.1	0.3	0.8	0.3
Chile	0.9	1.2	0.8	0.8	0.6	1.0	0.5	2.4
EU27	0.5	0.8	0.5	0.5	1.1	0.6	0.7	0.2
India	1.3	1.1	1.0	1.0	0.5	1.6	0.4	1.3
Indonesia	0.8	0.0	0.7	0.8	1.3	0.6	1.8	3.0
Japan and Korea	0.7	0.4	1.2	0.2	0.4	1.0	0.7	0.5
Malaysia	1.2	-	1.3	0.9	1.3	1.2	1.8	3.0
Mexico	0.4	1.4	1.2	-	1.1	1.6	1.4	2.2
Morocco	0.6	1.6	1.2	1.1	0.4	1.3	0.2	2.4
Russia	0.7	0.8	0.4	1.2	0.5	0.9	0.4	2.2
South Africa	0.0	0.7	1.2	1.4	1.6	1.0	1.8	2.5
Turkey	-0.2	0.8	1.1	0.4	0.8	0.5	0.6	3.0
United States	1.0	0.6	0.9	1.9	1.1	0.5	0.6	0.8
Rest of Europe	0.5	0.9	0.6	1.3	1.3	0.9	0.6	0.7
Rest of Central and South America	0.9	1.2	1.3	0.8	0.6	1.0	0.5	2.3
Rest of Africa	1.5	1.3	1.2	1.6	1.3	1.5	1.5	3.3
China	1.1	1.7	1.6	1.8	1.9	1.9	1.2	2.7
Rest of Oceania	0.0	1.0	1.6	1.1	0.8	1.3	0.7	2.3
Rest of Asia	1.2	0.8	1.1	1.9	0.8	1.2	0.6	1.3

Source: PBL (2012); OECD (2012).

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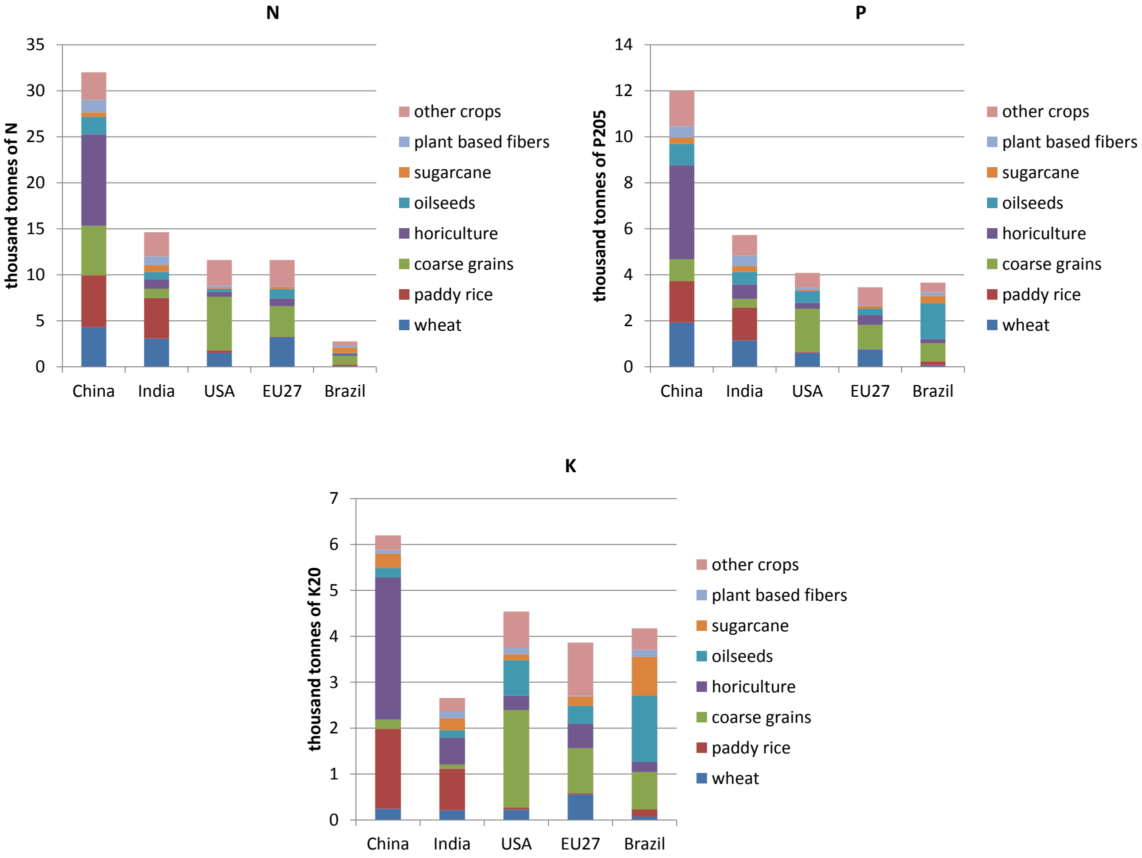
Annex 2

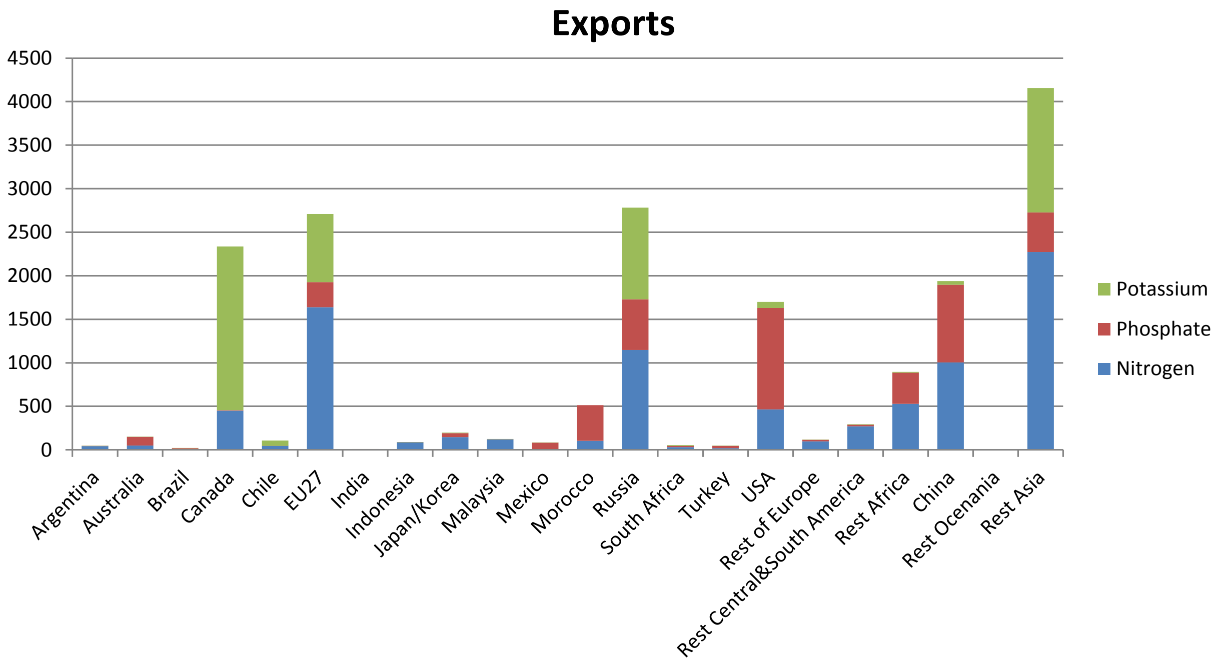
Supplementary information and model results

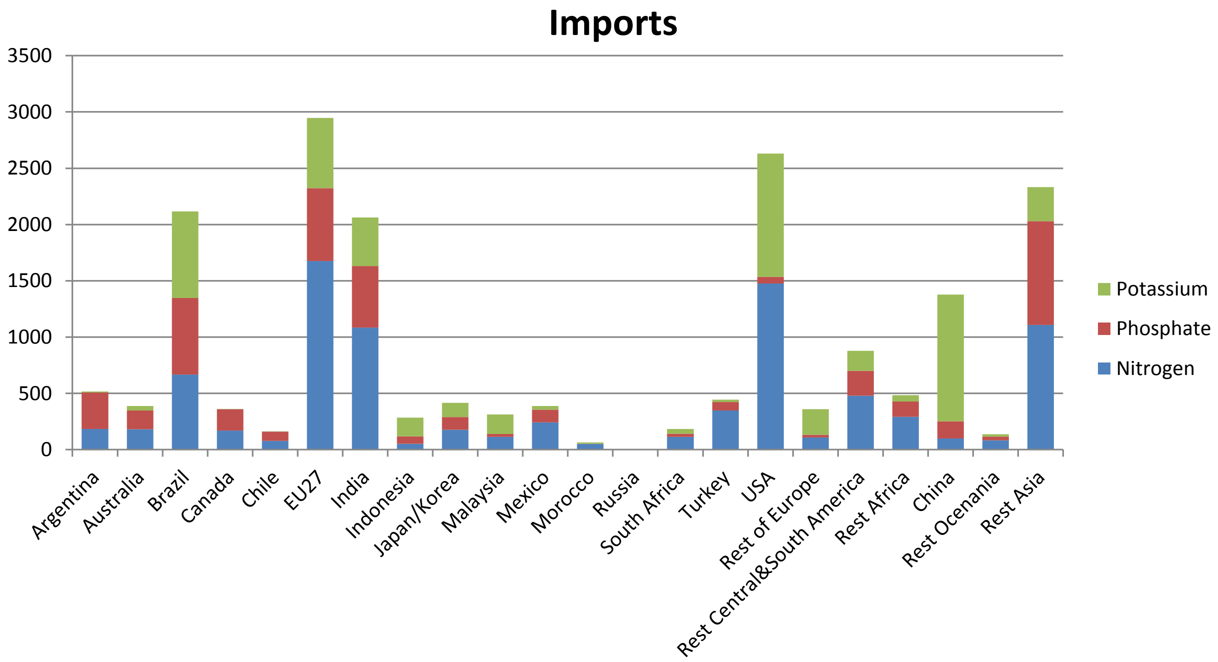
Figure A.3. Nutrient consumption per sector and per region in 2007



Source: Heffer, 2009.

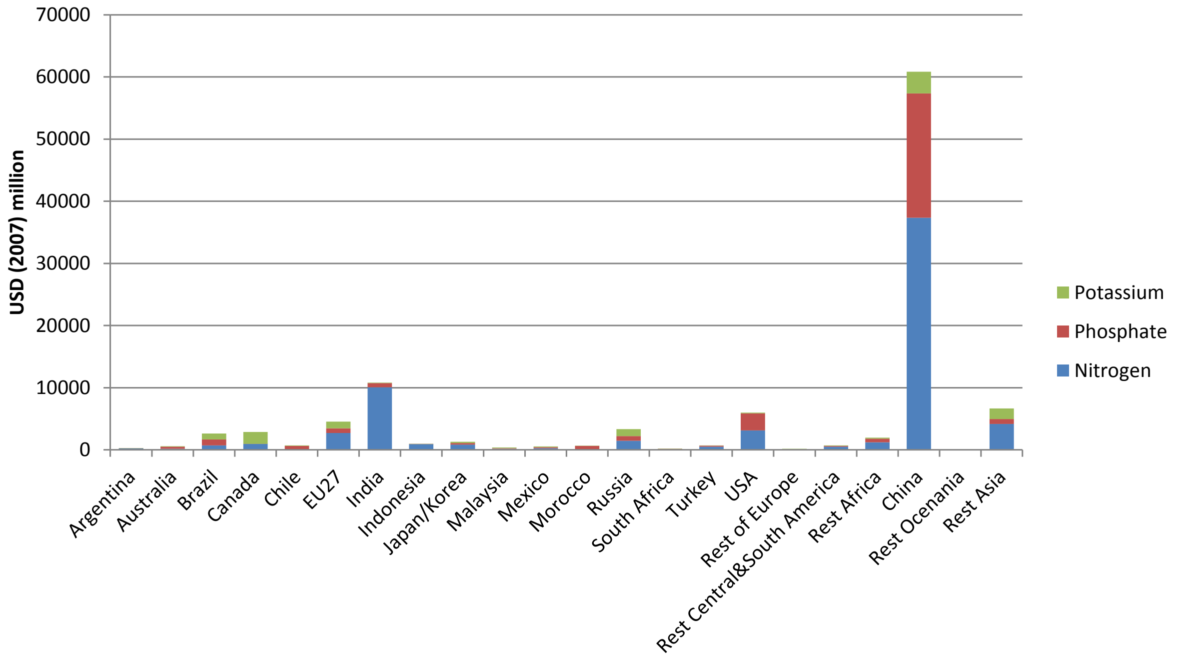
Figure A.4. Exports and imports of fertiliser nutrients, 2007, in million 2007 USD





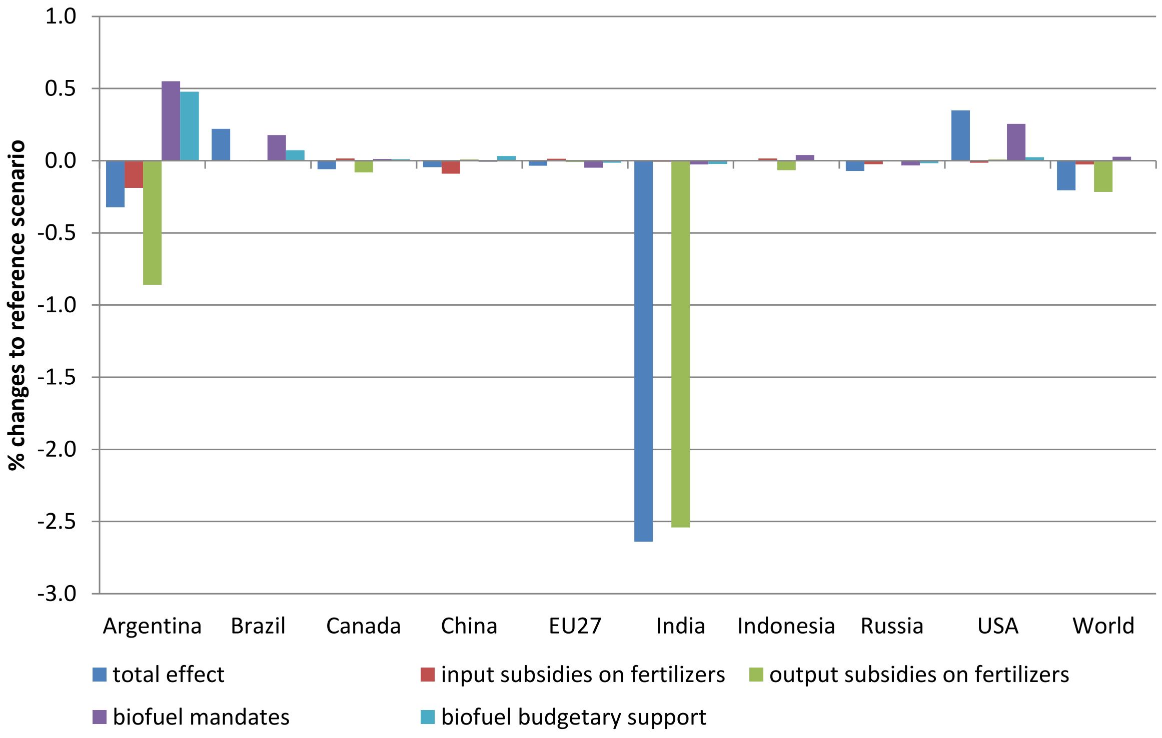
Source: Own calculations based on BACI, IFA (2013).

Figure A.5. Production value of fertiliser per region and per nutrient



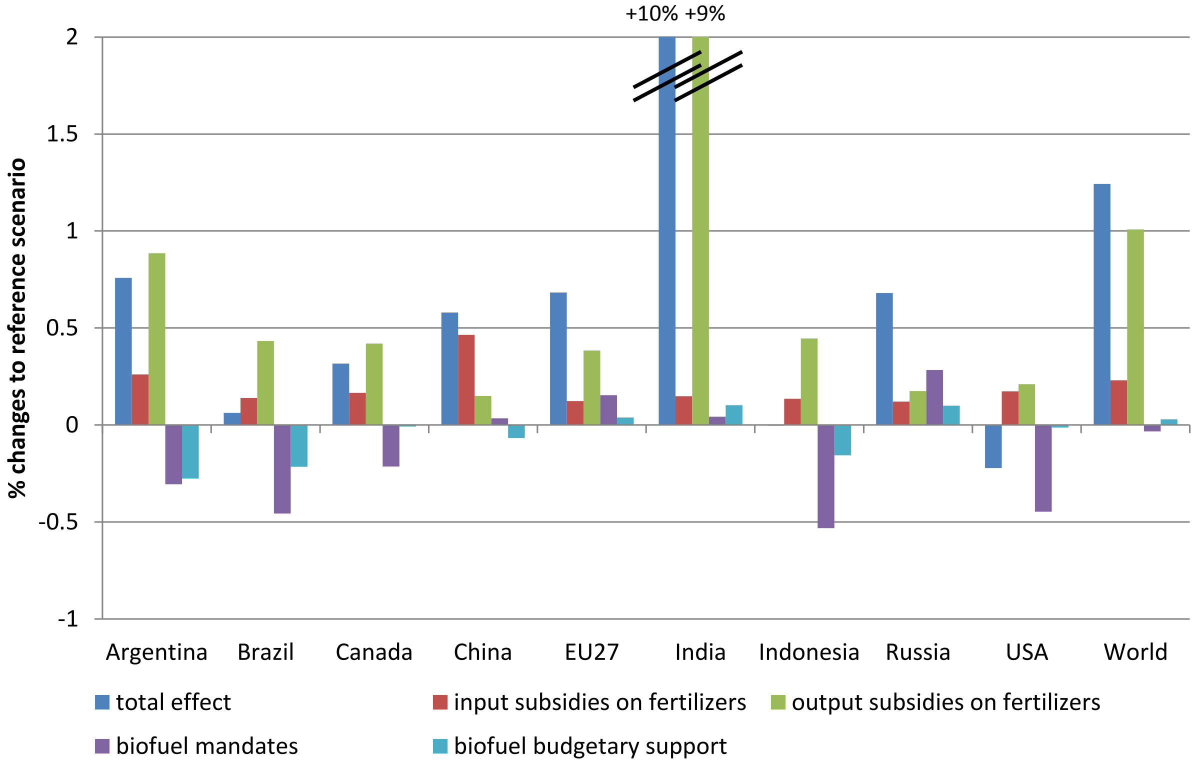
Source: Own calculations based on BACI, Heffer (2009), IFA (2013).

Figure A.6. Impacts on livestock production, counterfactual scenario, 2025



Source: MAGNET simulation results.

Figure A.7. Impacts on livestock prices, counterfactual scenario, 2025



Source: MAGNET simulation results.