Implications of the Biofuels Boom for the Global Livestock Industry: A Computable General Equilibrium Analysis

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1. Introduction and literature review

The global biofuel industry has experienced a period of extraordinary growth around the world in recent years and is expected to grow in the future. The rapid growth of biofuel industry has important consequences for the farms producing biofuel feedstocks such as corn, sugarcane, and oilseeds, and most studies to date have focused on these crop sector impacts. However, the biofuel expansion has significant implications for the global livestock industries as well. The purpose of this paper is to delve more carefully into the impacts of expansion of biofuel production for the global livestock industries.

The most obvious consequence of large scale biofuel production for the livestock industry is higher crop prices which raise input costs. Biofuel production also raises returns to cropland, which, in turn, encourages conversion of some pastureland to crops. On the other hand, biofuels are produced in conjunction with valuable byproducts which can be used in the livestock industry as animal feeds and can substitute for the higher priced crops in animal rations. Production of biofuel byproducts such as Distillers Dried Grains with Solubles (DDGS) and oilseed meals have significantly increased in recent years following the boom in biofuel production. For example, production of DDGS within the United Sates (US) has increased from 5 million metric tons in 2001 to about 20 million metric tons in 2007. During the same period, production of rapeseed meal within the European Union (EU) has increased from 5 million metric tons to 10 million metric tons. The prices of these byproducts have declined[1], relative to

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[1] For example, in the US average price of DDGS has increased by 39.9% during 2001-2007, while the average price of corn, a major feedstuff, has increased by 84.4% during the same period.

other feedstuffs, and, as a result, their importance in the feed mix has risen. This suggests that biofuel byproducts can help to offset some of the adverse cost implications of the biofuels boom for the livestock industry.

The implications of large scale biofuel production for the livestock industry are not uniform across regions, or across livestock types. The strongest impacts are being felt in those countries which are actively pursuing biofuel mandates (e.g. US and EU), as well as those countries which are closely tied into the global agricultural economy. The impacts across different livestock sectors are also quite diverse. For example, dairy and beef producers traditionally use DDGS in their feed rations and are therefore better positioned to gain from increased DDGS availability, compared to other livestock producers who may not be able to adjust their feed rations as readily to absorb the increased supply of DDGS.

The relationship between the biofuel and livestock industries is a two way street, since the livestock industry also can affect the biofuel industry. Biofuel byproducts represent an important component of biofuel industry revenues (Taheripour et al., 2008). If the livestock industry could not absorb these byproducts, their prices would fall sharply, thereby limiting expansion of the biofuel industry. In addition, both industries compete for inputs in the crop market. The interactions between these industries get more complicated when we take into account other economic activities and their interactions with energy and agricultural markets. For this reason, a formal model is required in order to provide a comprehensive evaluation of consequences of biofuel production for the global livestock industry.

Several aspects of biofuel production have been examined in the literature. A few papers have used partial equilibrium models to examine welfare implications of biofuel policies. For example, de Gorter and Just (2009) find that the US ethanol tax credit leads to a loss in social

welfare by $1.3 billion. Gardner (2007) estimates the welfare due to the US ethanol subsidy to be $91million the short run and $6.65 billion in the long run. Khanna, Ando, and Taheripour (2008) show that the US ethanol subsidy of $0.51 per gallon leads to a loss in social welfare (relative to a set of optimal tax rates including a tax on carbon emissions) of $19 billion. Ando, Khanna, and Taheripour (forthcoming) show that the welfare costs of the US ethanol mandates for 2015 relative to the socially optimal policy (including a tax rate on emissions) ranges from $60 billion to $115 billion depending on the elasticity of gasoline supply.

Many studies have examined the use of biofuel byproducts and their suitability for different types of animal species (Shurson and Spiehs, 2002; Anderson et al., 2006; Whitney et al., 2006; Daley, 2007; Klopfenstein, Erickson, and Bremer, 2008a and 2008b; Schingoethe, 2008; Stein 2008; and Bregendahl, 2008). In general, these papers indicate that distiller grains can be introduced in animal feed rations more extensively at heterogeneous rates across different types of species. A group of studies has estimated huge potential markets for these products based on purely theoretical feed rations (Cooper, 2005; Dhuyvetter et al., 2005; Fox, 2008; Paulson, 2008). Some studies have used partial equilibrium models and examined impacts of biofuels on grain and livestock industries. For example, Elobeid et al. (2006) and Tokgoz et al. (2007) have studied impacts of ethanol production on the US grain and livestock industries using partial equilibrium models. The former work did not take into account possibility of using ethanol byproducts as animal feed and hence its results are not likely to be accurate, however the latter one did include distiller grains in its analysis and shows moderate effects of ethanol production on the US livestock industry.

Finally, several studies have used Computable General Equilibrium (CGE) models and addressed the economy-wide consequences of producing biofuels at a large scale (Reilly and

Paltsev, 2007; Dixon, Osborne, and Rimmer, 2007; Banse et al., 2007; and Birur et al., 2007)

These papers have ignored the role of byproducts resulting from the production of biofuels; hence they do not provide an accurate evaluation of economic consequences of biofuel production, in particular for the livestock industry, which is the main user of biofuel byproducts. In a recent work, Taheripour et al. (2008) introduced biofuel byproducts into a special purpose version of the Global Trade Analysis Project (GTAP) model and have shown that incorporating biofuel byproducts considerably dampens the impacts on land use and commodity prices in the face of 2015 US and EU biofuel mandates (we will henceforth refer to this paper as THTBB).

Hertel, Tyner, and Birur (2008) have further extended this framework to evaluate impacts of the US and EU biofuel mandates for the world economy (we will henceforth refer to this paper as HTB). Unlike earlier papers in this field which have focused on the individual, national impacts of biofuel mandates, HTB has examined interactions among these policies as well. It shows how the presence of each of these policies and their combination influence global markets and land use around the world. THTBB and HTB evaluate impacts of mandates on production, consumption, exports, and imports of 18 groups of commodities across the world, divided into 18 regions. In this earlier work, THTBB and HTB have aggregated all livestock activities into one sector. So they do not provide information on the differential consequences of biofuel production for the different elements of the livestock industry. In addition, they utilized an aggregated food sector in their model which covers food, feed, and vegetable oil industries under one umbrella. As a result, one cannot see differential consequences of biofuel production for these activities. This makes it particularly hard to evaluate the link between increased biodiesel production and the vegetable oils and oilseeds industries.

In this paper we extend earlier work of HTB and THTBB in several directions to investigate the consequences of biofuel mandates for the world economy with an emphasis on livestock industries. Specifically, we further disaggregate economic activity in the economy with an aim of better understanding the linkages among biofuel production, byproducts, feedstuffs and livestock production. In addition, we introduce a new approach to modeling biodiesel production. In our earlier work we assumed that the biodiesel industry uses oilseeds, along with other inputs, to produce biodiesel with oilseed meal as the byproduct. This is a valid assumption, but it bypasses the link between the vegetable oils and biodiesel industries. In addition, it ignores the fact that a large portion of oilseed meals are produced by the vegetable oil industry. In this paper we introduce two new industries which produce crude and refined (edible) vegetable oils. The crude vegetable oil industry crushes oilseeds and produces crude vegetable oil and oilseed meal as the joint products. In the new setup, the biodiesel industry uses crude vegetable oil and produces only biodiesel. Finally, in this paper we examine the world-wide welfare implications of biofuel mandates as well.

According to the simulation results presented in this paper, the biofuel mandate programs are expected to sharply increase production of coarse grains in the US, sugarcane in Brazil, and oilseeds in the EU. The biofuel mandates also serve to reduce production of the livestock and processed livestock industries in the biofuel producing regions. At the global scale, the processed dairy and processed non-ruminant industries will experience more reduction in their outputs due to the price impacts of mandates. The numerical results suggest that the biofuel mandates reduce food production in most regions while they raise crude vegetable oils in almost all regions across the world and in particular in the EU region.

Implementing biofuel mandates in the US and EU will increase cropland within the biofuel and non-biofuel producer regions. A large portion of this increase will be obtained from grass lands. The biofuel producing regions are expected to reduce their coarse grains exports and increase imports of oilseeds and vegetable oils. The ruminant meat industry benefits more from the expansion of DDGS than other livestock activities. Finally, while US and EU will experience significant welfare losses due to their combined biofuel mandates, Brazil gains significantly from the US and UE biofuel mandates. Oil exporting regions including the Middle East and Russia suffer significantly from the US and EU biofuel mandates, while Japan, India, and East Asia show considerable gains.

2. Analytical framework

This paper seeks to isolate the impacts of biofuel mandates in the US and the EU on the global structure of the livestock industry. Given this goal, we need a model which is global in scope, and which links global production, consumption and trade. In addition, the model should properly link energy, biofuel, and agricultural markets. Since biofuel, crop, and livestock industries compete through the land market, the model should link these activities through the land market as well. Furthermore, biofuels byproducts, which can be used in animal feed stuffs, bridge these industries through a triangular relationship which could alter the nature of competition among these industries. All of this has led us to the development of a special purpose version of the Global Trade Analysis Project (GTAP) model (Hertel, 1997) of the global economy. We adopt as our starting point for this paper, the work reported in THTBB and HTB. The former paper introduced biofuel byproducts into the GTAP modeling framework, and the latter analyzed the consequences of the US and EU biofuel mandate policies for the global economy and their land use implications. These two papers have applied a special GTAP

database which was developed by Taheripour et al. (2007) and disaggregates three biofuels sectors within version 6 of the original GTAP database.

In the rest of this section we first introduce this database along with modifications which we made to handle the new model. Then we review the major features of THTBB and HTB frameworks accompanied by an explanation of the US and EU mandates. Finally, we explain alterations to the model for the present paper.

GTAP-BIO data base and its modification

Version 6.0 of the GTAP database covers 87 countries and 57 commodities that represent the world economy in 2001 (Dimaranan, 2006). This database does not explicitly show production, consumption, and trade of biofuels. Taheripour et al. (2007) introduced biofuels into this database. We will henceforth refer to this database as GTAP-BIO. The GTAP-BIO database contains data on the following three types of biofuels as well:

i)   Ethanol from coarse grains, called Ethanol-1

ii)   Ethanol from sugarcane, called Ethanol-2

iii)   Biodiesel from oilseeds, called Biodiesel

This database has been developed according to the values of produced biofuels across the world in 2001. In addition, several plant-level biofuel processing models have been used to introduce biofuel production technologies into the extended database. The GTAP-BIO database, following its original version, includes an industry which represents the aggregated food industry. This industry covers all processed food and animal feed commodities. The database also includes an industry which represents all types of vegetable oils (crude and edible). Both THTBB and HTB have applied an aggregated version of this database which covers 18 industries

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and 18 regions. In addition, they have introduced DDGS as a byproduct of the grain based ethanol industry, and oilseed meal as the byproduct of the biodiesel industry. In this earlier version of the GTAP-BIO database one sector covers all livestock industries and one sector covers all food, feed and vegetable oil industries.

In this paper we extend the GTAP-BIO database in several directions to properly trace the link among the biofuel, vegetable oil, food, feed, and livestock industries. We first distinguish between feedstock of the US and EU ethanol industries. In the first version of GTAP-BIO database the US and EU both use coarse grains to produce ethanol. In the modified database, the US uses corn and EU uses wheat. Then we split the "other food products" industry[2] into two distinct industries: processed food and processed feed. We also split the vegetable oil sector[3] into two distinct industries: crude vegetable oil and refined vegetable oil. The crude vegetable oil sector uses oilseeds and produces crude vegetable oil (as the main product) and oilseed meal (as the byproduct). Unlike the GTAP-BIO database we use a biodiesel production technology which uses this crude vegetable oil and other inputs to produce biodiesel. Finally, we aggregate the modified GTAP-BIO database into 28 industries, 30 commodities, and 18 regions. The revised database covers three distinct livestock industries: dairy farms, ruminants and non-ruminants. Appendix A lists sectors, commodities, and regions presented by the modified aggregated database.

Byproducts in the GTAP model

In the original GTAP model, and its extensions, each sector only produces one commodity. THTBB altered this setup to handle joint products in the GTAP framework. In

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[2] Represented by ofdn in the GTAP-BIO database.
[3] Represented by voln in the GTAP-BIO database.

particular, on the supply side of THTBB, the grain based ethanol sector produces ethanol and DDGS as joint products, and the biodiesel sector produces biodiesel and oilseed meal jointly. On the demand side of THTBB the livestock industry uses biofuel byproducts. THTBB combines DDGS produced by ethanol industry, meals produced by biodiesel industry, and inputs from agricultural and food industry to generate a feed input for livestock industry. While this setup captures the competition between the biofuel byproducts and the traditional feed stuffs within the animal feed rations, it does a poor job capturing the magnitude of oilseed meals produced by the crude vegetable oil industry. To model the role of oilseed meals in the livestock industry more accurately we change the feed demand structure of THTBB in the following way. We keep the substitution between the DDGS and coarse grain with no change, but we combine oilseed meals produced by the crude vegetable oil industry with other traditional animal feeds produced by the feed industry. Specifically, we have introduced the following nested demand structure in the livestock sectors of the model:
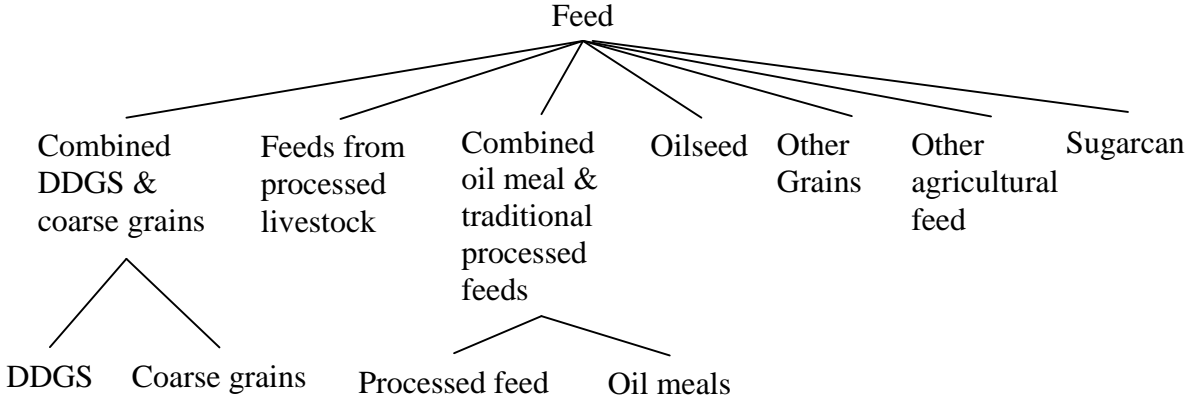
We applied a value of 50 for the elasticity of substitution between oil meal and traditional processed animal feeds in the three livestock industries feeding structure to replicate the price path of rapeseed meal in the EU. We used values of 20, 30, and 10 for the elasticities of

substitution between coarse grains and DDGS in the dairy farms, other ruminant, and non-ruminant feed structure, respectively, to account for their differential abilities in digesting DDGS[4]. Finally, following Keeney and Hertel (2005) we used 0.9 for the elasticity of substitution at the higher level of the feed demand

Modeling biofuel mandates in GTAP

Birur, Hertel and Tyner (2007) add biofuels into the GTAP-E model (Burniaux and Truong, 2002 and McDougall and Golub, 2007), which has been widely used for analysis of energy and climate change policies. Those authors augment this model by adding the possibility for substitutability between biofuels and petroleum products. As mentioned earlier, THTBB introduce byproducts into this model and HTB augment the model with a land use module, nick-named GTAP-AEZ – where the AEZ stands for Agro-Ecological Zones (Hertel et al., 2008) to accurately depict the global competition for land between food and fuel. This disaggregates land use into 18 AEZs which share common climate, precipitation and moisture conditions, and thereby capture the potential for real competition between alternative land uses. Land use competition is modeled using the Constant Elasticity of Transformation (CET) revenue function, which postulates that land owners maximize total returns by allocating their land endowment to different uses, subject to the inherent limitations on land use change.

HTB validate this model against actual observations for energy and biofuel markets over the time period: 2001-2006, and then generate a baseline scenario to simulate the impacts of biofuel expansion for the world economy in this time period. In this simulation HTB shock only those drivers that were key factors in shaping the EU and US biofuel economy over this period – namely the price of petroleum, biofuel policies in the US and the EU, and the ethanol additive

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[4] Arora, Wu, and Wang (2008) have calculated corn-DDGS displacement ratios for livestock industries.

requirements in the US. With this approach, HTB impose the 2006 biofuel economy on the observed 2001 global economy, while abstracting from all other factors which changed in the time period of 2001-2006. Then HTB uses the baseline scenario as a starting point and simulates a forward- looking scenario to analyze the EU and US biofuel mandates in 2015.

From the baseline simulation HTB conclude that, in the US, the rising oil price was the most important contributor to the biofuel boom in that country, followed by the MTBE additive ban. In the EU, fuel tax exemptions were the most important factor in driving biofuel growth, followed by oil prices.

The HTB forward-looking scenario shows that prices, production and land area devoted to key biofuel crops (corn in the US and oilseeds in the EU) will be substantially increased within the US and EU due to their biofuel targets defined for 2015. According to HTB results, mandates defined for 2015 will adversely affect the livestock industry. HTB results also indicate that the strongest interaction between the US and EU mandates is for oilseed production in the US, where much of the increase in output is expected to be due to the presence of EU mandates, as opposed to US mandates. The other area where mandates have important interactions is in the aggregate demand for crop land. About one-third of the growth in US crop cover is attributed to the EU mandates. HTB also conclude that crop cover is likely to rise sharply in Latin America, Africa and Oceania as a result of the US and EU biofuel mandates. These increases in crop cover come at the expense of pasturelands and forest and have potentially adverse consequences for global GHG emissions.

Biofuel mandates and livestock industries

In the present paper we extend the HTB model and its simulation approach to analyze the consequences of the US and EU mandates for the livestock industries. In so doing, we extend the

land use module by disaggregating pasturelands between dairy farms and the ruminant meat industries. The non-ruminant industry does not use significant inputs of land. We also incorporate other necessary changes in the HTB modeling structure to match it with the requirements of the new database which we generated for our analysis. We calibrate the new model to the revised 2001 data base and then we run a baseline scenario to create the 2006 benchmark, following the approach of HTB. Then we run a 2015 mandates scenario to investigate impacts of the US and EU renewable fuels policies for the global livestock economy.

The particular mandate which we consider for the US is based on the US Energy Independence and Security Act of 2007, which targets 15 billion gallons of corn-based ethanol use by 2015. In the EU, the target is 5.75% of renewable fuel use in 2010 and 10% by 2020. However, there are significant doubts as to whether these goals are attainable. Indeed, there is already evidence that the EU will scale back these ambitious goals. Therefore, for this analysis, and following HTB, we adopt the more conservative mandate of 6.25% renewable fuels in transportation by 2015 in the EU. As mentioned earlier, we first run a baseline scenario to simulate the world economy in 2006 and generate a database for this year. Then we use the 2006 database to simulate the world economy in 2015 in the presence of the US and EU mandate. Following HTB, we abstract from changes in other exogenous variables and capture only consequences of biofuel mandates. To reduce the size of this report we only focus on the results of our forward-looking policy scenario in the next section and we highlight the impacts on the livestock industries.

3. *Ex ante* analysis of US and EU biofuel mandates

In this section, we analyze impacts on production, consumption, and trade of those commodities which are keys in understanding the consequences of mandates for livestock

industry. We also provide some simulation results which measure impacts of the mandates on the cost and production structures of livestock industries. The land use implications of mandates will be discussed as well. At the end we present the global welfare implications of mandates. While interested readers may request a copy of solution archives of our simulation results, in what follows we highlight key results. In particular, in some cases, we divide the whole world into four regions: Biofuel producing regions including US, EU, and Brazil and Non-biofuel producing region (including all other regions and counties which do not produce biofuels) to summarize the results.

Impacts on outputs

Biofuel mandates are expected to sharply increase production of coarse grains in the US (by $2.4 billion, or about 10.5%), sugarcane in Brazil (by $1.4 billion or 25.2%) and oilseeds in EU (by $3.5 billion, or 42.8%), all at constant prices and measured relative to our baseline 2006 benchmark (Table 1 and Figure 1). On the other hand, the mandates significantly depress production of some other crops in these biofuel producing countries as cropland is diverted to biofuel feedstocks. For example, mandates are estimated to reduce production of other agricultural commodities in US (by $1.8 billion, or about -2.7%), Brazil (by $1.0 billion, or -10.2%), and EU (by $4.8 billion, -4.0%). This indicates that biofuel mandates alter the production pattern of agricultural commodities within biofuel producing regions. The biofuel mandates induce changes in crop production in many non-biofuel countries as well. For example, as shown in Table 1 the US and EU mandates are expected to increase production of oilseeds in the non-biofuel region by $3.3 billion (or 7.1%). In general, mandates serve to boost production of agricultural commodities in non-biofuel regions by about $7.6 billion (Table 1 and Figure 1).

While mandates boost production of crop commodities globally, they serve to reduce production of the livestock and processed livestock industries in many regions and in particular within the biofuel producing regions. Table 2 shows that the overall global volume of livestock and processing livestock industries is expected to fall by about $6 billion (or -0.4%). About 91% of this reduction will take place within biofuel producing regions, US 25%, EU 45$, and Brazil 21%. As shown in Table 2 and Figure 2, while all types of livestock and processing livestock industries within the biofuel producing regions experience reduced output, in the US the non-ruminant, within the EU the processed dairy product, and in Brazil the processed non-ruminant industries show the greatest output volume reduction due to the mandates. Biofuel mandates are also expected to increase productions of oilseed meals in EU by $5 billion or 115% and of DDGS in US by $2 or 189% (Figure 3). Later on in this paper, we will show that these sharp increases in byproducts induce major changes in feed rations.

Impacts on inputs and outputs prices

The biofuel mandates significantly increase the price of cropland all across the world, and in particular in US, EU and Brazil (Table 3). Our simulation results indicate that price of cropland is expected to increase by 48.6%, 107.3%, and 129.9% in US, EU and Brazil, respectively. This encourages transformation of pastureland to cropland which in turn leads to higher pastureland prices. As shown in Table 3, the price of pastureland is expected to increase by 16.3%, 35.2%, and 45.1% in US, EU, and Brazil, respectively. This could elevate costs of production in livestock industries. While biofuel mandates serve to increase price of land, they serve to reduce prices of capital and labor moderately all across the world, with few exceptions noted in Table 3. Biofuel mandates also significantly increase crop prices across the world (Table 4). For example, the prices of coarse grain, oilseeds, and sugarcane climb by 11.4%,

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26.3%, and 60%, respectively in US, EU, and Brazil. The higher crop prices adversely affect livestock industry and raise animal feed costs. On the other hand, mandates generate a considerable volume of DDGS and oilseed meals with lower prices compared to crop prices. For example, while the prices of coarse grains used in the US and EU livestock industries are expected to climb by 11.4% and 5.8%, the prices of DDGS in these regions change by 3% and -3.9% due to mandates. Table 4 also indicates that the prices of oilseed meals and processed feeds are projected to increase in most regions with rates considerably lower than the changes in crop prices.

Using more DDGS, oilseed meals, and processed feedstuffs in feed rations helps livestock producers, in particular in US and EU, to curb their use of the more expensive crops and also use less land in their production process. As the result, prices of livestock and processed livestock commodities only increase moderately across the world due to biofuel mandates. As shown in Table 5, prices of products of livestock industries increase between 1% to 3% across the world, with some exceptions for Brazil, Middle East and North Africa, and Sub Saharan Africa. This table also shows that, in general, prices of outputs of processed livestock industries moderately climb by growth rates between 0.0% to 1.0% with few exceptions for again Brazil and Middle East.

In general, as shown in Figure 4, prices of all types of livestock outputs are expected to significantly fall compared with grain prices in the US and EU regions. However, in these two regions outputs prices may fall moderately or increase compared with DDGS and oilseed meals prices. Later on when we analyze the impacts of biofuel mandates on the feed rations, we will see how livestock producers respond differently to the changes in prices of feedstuffs.

Impacts on household demands

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Here we consider impacts of biofuel mandates in household demands for major food items such as processed dairy products, processed ruminant products, processed non-ruminant products, edible oil, beverage-tobacco-sugar-processed rice, and other food products. In general, biofuel mandates are expected to reduce household demands for items mentioned above across the world (Table 6). However, magnitudes of reductions are not identical across the world. The magnitudes of reductions in demands for food items mentioned above in the US and EU are much higher compared to other regions. The overall reductions in food demands in these two regions are about $1.7 billion and $2.9 billion at 2006 constant prices, respectively. The biofuel mandates also significantly reduce demands for food items in Middle East and North Africa (by $1.2 billion). The overall reduction in the world demand for food products is about $9 billion of which 35% is related to reduction in demands for processed livestock products. The overall reduction in household demand for edible oil is about $0.5 billion.

While magnitudes of changes in demands for food items mentioned above compared with 2006 are relatively high, in particular in US, EU, and Middle East & North Africa, their percentage changes are usually small and less than 1.5% across the world. The heist rates of reductions in demands for food items belong to the Middle East & North Africa according to our simulation results. Among food items, the highest rate of reduction in household demand is related to edible oil.

Impacts on land use

The biofuel mandates are expected to affect the level and distribution of global land cover. Table 7 presents land cover impacts for all regions across the world. This table indicates that mandates are expected to increase croplands and reduce forest and pasture land in almost all regions across the world, with few exceptions. In general, mandates are expected to increase

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global cropland cover by about 13.33 million hectares. About 46% of changes in the crop areas are projected to occur in the biofuel producing regions themselves and the rest will take place in other regions. Among non-biofuel regions Canada and Sub Saharan Africa also devote considerable amount of lands to crop production. Table 7 also indicates that about 11.01 million hectares of pasturelands (84% of changes in croplands) are shifted to crop production due to mandates. Only about 2.6 million hectares of forest are expected to move to crop production due to mandates. These figures indicate that the livestock industries will lose a considerable amount of land due to the US and EU biofuel mandates (see Figure 5). Of course these are all *net changes in land cover*. In practice, pasture land may move into crops and forest land may move primarily into pasture.

Impacts on trade

The biofuel mandates alter global trade pattern for coarse grains, oilseeds, crude and refined vegetable oils, and livestock and processed livestock products. Table 8 represent changes in volumes of exports and imports of these commodities evaluated at constant 2006 fob prices for US, EU, Brazil, and non-biofuel regions. As shown in table 8, mandates reduce net exports of US coarse grains by $495.1 million and increase its net exports of oilseeds by about $960.6 million. The mandates only have minor impacts on the net exports of vegetable oils and livestock products of these regions. The biofuel mandates are expected to significantly hit EU exports and imports of oilseeds and vegetable oils. Table 8 shows that the EU net exports of oilseeds and vegetable oils are projected to fall by about $4439.5 million and $879.1 million. Mandates also reduce net exports of EU livestock and processed livestock products by $464.4 million. Net exports of Brazil oilseeds and vegetable oil are expected to increase by $586.7 million and decrease by $714.8 million. The net exports of commodities mentioned above for non-biofuel

regions are projected to increase, In particular, as shown in Table 8, the net exports of oilseeds and vegetable oils from these regions are expected to increase by $2892.2 million and $964.5 million. Figure 6 compares impacts of mandates on the net exports of key commodities for biofuel and non-biofuel regions.

We now analyze the impacts of mandates on the commodity-specific, as well as regional trade balances (see Table 9). In general, while mandates improve the US trade balance by $3800.8 million, they serve to reduce trade balances of EU, Brazil, and non-biofuel regions by $1869.3, $251.1, and $1680.4 million. It is important to note that the increase in trade deficit of EU is related to agricultural commodities. The EU members need to import significant amount of these commodities to satisfy their biofuel goals. As shown in Table 9, all biofuel producing regions will suffer from a reduction in their livestock and processed livestock trade balances, however the magnitudes of these reductions are not large.

While the US will exports more animal feeds and gets benefits from a positive trade balance from this group of commodities (mainly due to an increase in the exports of DDGS), the EU and Brazil increase the value of their animal feed imports in the presence of the US and EU mandates. The non-biofuel fuel producing countries will also increase net imports of animal feeds (by about $1.9 billion) due to the US and EU mandates. The changes in the trade balances of food products (including processed food, refined vegetable oil, tobacco, beverage, sugar, and processed rice) in the US, EU, and Brazil are equal to $200.8 million, $-33.1 million, and -883.9 million, respectively. Finally, it is important to mention that the non-biofuel regions improve their trade balance in agricultural products (by $7566.6 million), livestock and processed livestock products (by $693.5 million), and food products mentioned above (by $478.9 million).

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However, the non-biofuel producer region will face a large reduction (11472.7) in their trade balance for other goods and services.

Impacts on composite animal feeds

Appendix B represents the composition of animal feeds in livestock industries with and without mandates. These shares are calculated at constant prices and therefore only reflect changes in feed intensity. This appendix indicates that mandates mainly alter the composition of animal feeds in the US and EU with marginal changes in other regions. The mandates will significantly reduce the share of coarse grains in feed rations in the US and EU and raise shares of DDGS and oilseed meals across all livestock industries (see Figures 7, 8, and 9).

The ruminant meats industry benefits more from the expansion of DDGS than other livestock activities. The share of DDGS in the feed composite of ruminant meats in the US is projected to increase from 4.5% to 13.8% due to mandates (Figure 8). The corresponding numbers for the dairy farms industry are 3.3% and 9.2% (Figure 7) and for the non-ruminant industry are 0.7% and 1.4% (Figure 9). This ability to absorb biofuel byproducts cushions the decline in ruminant and dairy farm outputs in the US, which fall by less than half of the amount of non-ruminants (-0.4% vs. -0.9%, see table 2).

One can see a similar pattern of byproduct use in the EU. In this region the share of DDGS in the feed composite of ruminant meats industry increases from 1.5% to 9.5% (Figure 8) due to mandates. The corresponding numbers for the dairy farms industry are 0.9% and 4.5% (Figure 7) and for the non-ruminant industry are 0.2% and 0.4% in the EU region (Figure 9). However, this does not translate into lesser output reductions in ruminants in the EU, since the main biofuel product in the EU is biodiesel. Increased production of biodiesel results in a

reduction in oilseed meal prices and a strong increase in the feed intensity of this input in the EU across all the livestock industries, including non-ruminants.

Finally, Appendix B suggests that some regions such as Central & Caribbean America; South & other America; East Asia; Middle East & North Africa; and Sub Saharan Africa may be expected to introduce DDGS in their animal feed rations in the dairy and other ruminant industries.

Welfare implications

We now examine global welfare implications of the US and EU biofuel mandates. In this welfare analysis we use an *equivalent variation* measure (*EV*) with the following definition:

$$EV = e(p^0, u^1) - e(p^0, u^0), \ u^0 = v(p^0, m^0) \text{ and } u^1 = v(p^1, m^1).$$

Here $e(\ ,\ )$ and $v(\ ,\ )$ represent expenditure and indirect utility functions, p^0 and p^1 represent vectors of prices in the absence and presence of mandates, and m^0 and m^1 indicate values of endowments in the absence and presence of mandates, respectively. A positive amount of *EV* represents a welfare gain and vice versa. The GTAP program has a module which calculates *EV* for each region according to the definition mentioned above. The module also decomposes and determines major components the *EV* for each region. We modified this module to calculate and decompose *EV* of mandates in the presence of biofuels and their byproducts for all regions across the world. In general, mandates reduce world-wide welfare by about $37 billion (Table 10). While US and UE are expected to experience significant welfare losses (by $7.5 billion and $19.6 billion, respectively) due to their combined mandates, Brazil will get a major benefit (about $4.3 billion) from the US and EU biofuel mandates. The US and UE suffer significantly from inefficiencies due to their mandates (by about $14.5 billion and $23 billion). High subsidy

rates contribute significantly to these losses. However, their gains from improvement in terms of trade ($4.9 billion and $3.6 billion) eliminate a portion of their losses. A portion of these gains are due to higher crop prices. Among non biofuel regions, Middle East & North Africa and Russia suffer significantly (by $11.7 billion and $2.4 billion) due to the US and EU biofuel mandates. These regions suffer mainly due to changes in terms of trade. These regions will receive lower prices on their crude oil exports and pay higher prices for agricultural and food commodities. Among non biofuel regions Japan, East Asia, and India are expected to get some benefits ($2.4 billion, 1.3$ billion, and $1.2 billion, respectively) from the US and EU biofuel mandates.

4. Conclusion

In this paper, we offer a general equilibrium analysis of the impacts of US and EU biofuel mandates for the global livestock sector. Our simulation boosts biofuel production in the US and EU from 2006 levels to mandated 2015 levels. We show that mandates will encourage crop production in both biofuel and non biofuel producing regions, while reducing livestock and livestock production in most regions of the world. The non-ruminant industry curtails its production more than other livestock industries. The numerical results suggest that the biofuel mandates reduce food production in most regions while they increase crude vegetable oils in almost all regions. Implementing biofuel mandates in the US and EU will increase croplands within the biofuel and non-biofuel producer regions. A large portion of this increase will be obtained from reduced grazing lands. The biofuel producing regions are expected to reduce their coarse grains exports and raise imports of oilseeds and vegetable oils. While all livestock industries use more biofuel byproducts in their animal feed rations, the dairy and other ruminant industry benefit most from the expansion of DDGS. We finally conclude that, while biofuel

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mandates have important consequences for the livestock industry, they do not harshly curtail these industries. This is largely due to the important role of byproducts in substituting for higher priced feedstuffs. In addition, with relatively inelastic food demands, producers are able to pass much of the price rise on to consumers. In general, US, EU, Meddle East & North Africa, and Russia will experience significant welfare loses due to the combined US and EU mandates, while Brazil, Japan, India, and East Asia are expected to get major gains.

Table 1. Impacts of US and EU biofuel mandates designed for 2015 on the crop outputs (volumes are in $US million at constant 2006 prices)

Description	US	EU27	Brazil	Others	World
Volume Change:					
Coarse grains	2378.6	-1701.6	-183.8	514.1	1056.4
Other grains	-268.8	-277.6	-180.9	1355.5	605.3
Oilseeds	1154.1	3453.0	431.9	3334.4	8532.9
Sugarcane	-4.4	30.4	1362.4	4.5	1621.8
Other agricultural	-1790.1	-4768.3	-1043.6	2398.5	-5366.1
Percentage Change:					
Coarse grains	10.5	-9.0	-7.3	0.8	1.0
Other grains	-3.6	-1.5	-12.7	0.8	0.3
Oilseeds	8.5	42.8	6.7	7.1	11.4
Sugarcane	-0.2	0.6	25.2	0.0	4.3
Other agricultural	-2.7	-4.0	-10.2	0.5	-0.8

Table 2. Impacts of US and EU biofuel mandates designed for 2015 on outputs of livestock and processed livestock industries (volumes are in $US million at constant 2006 prices)

Description	US	EU27	Brazil	Others	World
Volume Change:					
Dairy farms	-111.8	-418.4	-13.0	-100.2	-646.0
Other ruminant	-130.5	-222.4	-226.4	-182.9	-768.8
Non-ruminant	-326.0	-489.1	-236.1	-136.0	-1192.5
Processed dairy products	-292.9	-920.2	-63.0	26.0	-1251.8
Processed ruminant	-318.9	-157.7	-351.5	-181.8	-1015.5
Processed non-ruminant	-321.4	-489.0	-376.9	59.2	-1134.0
Percentage Change:					
Dairy farms	-0.4	-0.8	-0.5	-0.1	-0.4
Other ruminant	-0.4	-0.8	-3.9	-0.2	-0.4
Non-ruminant	-0.9	-0.8	-4.4	-0.1	-0.4
Processed dairy products	-0.3	-0.8	-0.9	0.0	-0.4
Processed ruminant	-0.4	-0.2	-3.7	-0.2	-0.4
Processed non-ruminant	-0.5	-0.4	-7.9	0.0	-0.4

Table 3. Impacts of US and EU biofuel mandates designed for 2015 on primary inputs prices (Percentage Change)

Region	Cropland	Grassland	Unskilled Labor	Skilled Labor	Capital
USA	48.6	16.3	-0.4	-0.4	-0.1
CAN	59.9	16.1	-0.5	-0.5	-0.1
BRAZIL	129.7	45.1	1.0	0.9	2.1
JAPAN	12.9	4.5	-0.3	-0.4	-0.1
CHINA & Hong Kong	10.0	3.9	-0.5	-0.6	-0.2
INDIA	7.1	3.4	-0.1	-0.3	0.4
C. & Caribbean America	16.4	7.1	-0.4	-0.5	-0.3
S. & Other America	33.2	9.4	-0.5	-0.6	-0.4
East Asia	6.2	-0.3	-0.3	-0.3	0.2
Malaysia & Indonesia	10.3	4.5	-0.5	-0.6	-0.1
Rest of South East Asia	7.6	3.9	-0.3	-0.4	0.0
Rest of South Asia	6.1	2.5	-0.2	-0.4	0.2
EU27	107.3	35.2	-0.5	-0.5	0.1
Russia	14.4	4.1	-0.5	-0.6	0.5
Rest of Europe	32.2	12.9	-0.6	-0.7	-0.2
Middle E. & N. Africa	19.8	5.4	-1.4	-1.4	-1.1
Sub Saharan Africa	31.6	8.2	-0.4	-0.8	-0.4
Oceania	26.0	11.7	-0.2	-0.3	0.0

Table 4. Impacts of US and EU biofuel mandates designed for 2015 on crop prices used in livestock industries (Percentage Change)

Region	Coarse Grains	Other Grains	Oilseeds	Sugar-cane	Other Agri.	Proc. Feed	DDGS*	Oilseed Meals
USA	11.4	4.5	8.4	7.7	5.6	1.5	3.0	1.3
CAN	4.9	4.0	8.2	4.9	4.5	1.6	NP	2.2
BRAZIL	12.4	6.7	18.0	60.5	11.1	9.8	NP	11.8
JAPAN	8.1	2.3	9.7	1.0	1.3	2.5	NP	7.8
CHINA & Hong Kong	1.8	1.4	5.6	1.3	1.6	1.9	NP	5.2
INDIA	2.1	2.5	3.7	2.3	2.6	2.2	NP	-0.7
C. & Caribbean America	3.9	3.9	8.5	2.8	3.7	3.7	NP	3.2
S. & Other America	4.1	4.3	9.5	3.9	4.4	3.1	NP	2.7
East Asia	4.4	1.5	9.0	0.4	2.4	3.8	NP	3.8
Malaysia & Indonesia	3.1	2.9	9.4	2.7	3.4	1.9	NP	1.6
Rest of South East Asia	2.6	2.4	8.8	1.6	2.9	1.5	NP	-0.8
Rest of South Asia	2.3	2.2	3.4	1.6	2.0	1.9	NP	1.9
EU27	5.8	8.8	26.3	8.2	6.9	3.0	-3.9	0.3
Russia	1.8	1.9	7.1	2.2	2.2	1.1	NP	1.2
Rest of Europe	1.5	2.7	10.4	1.3	2.8	1.5	NP	1.2
Middle E. & N. Africa	4.3	3.6	9.0	0.5	1.2	2.5	NP	2.1
Sub Saharan Africa	2.3	3.8	7.3	1.6	2.6	1.4	NP	0.6
Oceania	4.3	3.6	9.1	2.9	3.2	1.3	NP	-0.1

* Regions with NP either do not producer DDGS or produce only negligible amounts.

Table 5. Impacts of US and EU biofuel mandates designed for 2015 on livestock and processed livestock prices (Percentage Change)

Region	Dairy Farms	Other Ruminants	Non-Ruminants	Processed Dairy Products	Processed Ruminants	Processed Non-Ruminants
USA	2.2	2.1	2.3	0.5	0.8	0.7
CAN	2.7	2.5	1.4	0.7	1.4	0.6
BRAZIL	9.7	7.7	3.0	4.4	4.5	3.5
JAPAN	1.4	2.7	1.2	0.1	1.0	0.2
CHINA & Hong Kong	1.4	1.3	0.7	0.1	0.5	0.4
INDIA	1.6	1.9	0.5	0.7	0.1	0.3
C. & Caribbean America	2.3	2.0	1.3	0.5	0.4	0.4
S. & Other America	2.3	2.0	0.8	0.8	1.0	0.7
East Asia	1.7	1.7	1.7	0.5	1.1	1.2
Malaysia & Indonesia	2.4	1.7	0.3	0.3	0.3	0.2
Rest of South East Asia	1.8	1.5	0.3	0.4	0.2	0.1
Rest of South Asia	1.1	1.6	0.3	0.6	0.7	0.6
EU27	3.4	3.0	1.9	0.9	0.9	0.7
Russia	0.4	0.5	0.0	0.1	0.2	0.0
Rest of Europe	1.8	1.7	1.4	0.3	0.3	0.3
Middle E. & N. Africa	0.0	-0.1	-0.4	-0.5	-0.2	-0.6
Sub Saharan Africa	0.6	0.6	0.1	0.1	0.4	0.0
Oceania	1.0	1.4	0.1	0.4	0.5	0.3

Table 6. Impacts of US and EU biofuel mandates designed for 2015 on the household demands for food product items (volumes are in $US million at constant 2006 prices)

Regions	Proc. Dairy	Proc. Ruminant	Proc. Non-Ruminant	Edible Oil	Toba., Bev., Sugar, & Proc. Rice	Other Processed Food
			Change in Volume			
USA	-203.0	-236.5	-227.0	-51.2	-405.8	-581.0
CAN	-26.6	-23.1	-12.8	-10.6	-23.8	-35.3
BRAZIL	-2.6	-7.2	5.0	-25.8	-142.1	21.5
JAPAN	-26.7	-52.2	-27.0	-17.9	-208.5	-182.9
CHINA & Hong Kong	-1.8	-3.3	-32.5	-8.2	-165.3	-121.3
INDIA	5.5	0.6	0.6	-4.3	9.0	-0.5
C. & Caribbean America	-28.6	-47.5	-62.3	-21.8	-96.9	-148.3
S. & Other America	-48.8	-61.2	-29.4	-22.0	-96.5	-116.6
East Asia	-5.7	-11.9	-21.7	-9.5	-41.1	-55.1
Malaysia & Indonesia	-1.7	-2.2	-3.3	-4.2	-37.6	-13.1
Rest of South East Asia	-1.4	-0.5	0.9	-2.2	-61.6	-10.2
Rest of South Asia	-0.6	-0.4	-1.2	-10.9	-24.4	-3.5
EU27	-472.3	-309.3	-382.5	-244.5	-563.1	-897.3
Russia	-32.6	-30.4	-86.5	-13.5	-74.9	-95.4
Rest of Europe	-41.7	-19.7	-30.8	-14.9	-99.0	-70.7
Middle E. & N. Africa	-122.0	-114.2	-178.9	-53.7	-339.9	-360.8
Sub Saharan Africa	-17.9	-38.6	-36.2	-14.0	-159.7	-102.1
Oceania	-3.8	-2.3	-1.5	-1.9	-9.3	-4.9
			Percentage Change			
USA	-0.5	-0.6	-0.5	-2.6	-0.3	-0.3
CAN	-0.4	-0.7	-0.4	-1.1	-0.3	-0.2
BRAZIL	0.0	-0.1	0.2	-1.1	-1.7	0.1
JAPAN	-0.2	-0.6	-0.3	-1.3	-0.2	-0.2
CHINA & Hong Kong	-0.3	-0.4	-0.3	-0.4	-0.3	-0.3
INDIA	0.1	0.3	0.2	-0.1	0.0	0.0
C. & Caribbean America	-0.3	-0.3	-0.3	-1.3	-0.3	-0.4
S. & Other America	-0.5	-0.5	-0.5	-0.7	-0.4	-0.4
East Asia	-0.2	-0.3	-0.4	-1.2	-0.2	-0.4
Malaysia & Indonesia	-0.2	-0.2	-0.2	-0.3	-0.3	-0.2
Rest of South East Asia	-0.1	0.0	0.0	-0.2	-0.3	-0.1
Rest of South Asia	-0.1	-0.1	-0.1	-0.6	-0.2	-0.1
EU27	-0.6	-0.6	-0.5	-1.0	-0.4	-0.5
Russia	-1.0	-1.1	-1.0	-1.4	-1.2	-0.9
Rest of Europe	-0.5	-0.5	-0.5	-0.9	-0.5	-0.6
Middle E. & N. Africa	-1.4	-1.4	-1.3	-1.6	-1.4	-1.4
Sub Saharan Africa	-0.9	-0.9	-0.9	-0.6	-0.6	-0.5
Oceania	-0.1	-0.2	-0.1	-0.3	-0.1	-0.1

Table 7. Impacts of the US and EU biofuel mandates designed for 2015 on land cover (figures are in millions of hectares)

Regions	Forestry	Cropland	Pastureland (Dairy Farms)	Pastureland (Other Ruminant)
USA	-0.29	1.22	-0.42	-0.52
CAN	-0.94	1.37	-0.12	-0.31
BRAZIL	-0.18	1.83	0.26	-1.90
JAPAN	-0.01	0.02	0.00	0.00
CHINA & Hong Kong	0.36	0.14	-0.11	-0.38
INDIA	-0.20	0.27	-0.07	0.00
C. & Caribbean America	-0.01	0.17	-0.10	-0.06
S. & Other America	0.74	0.53	-0.42	-0.85
East Asia	0.03	0.00	0.05	-0.08
Malaysia & Indonesia	0.01	0.01	0.00	-0.02
Rest of South East Asia	0.03	0.00	0.00	-0.03
Rest of South Asia	-0.03	0.08	-0.05	0.00
EU27	-2.38	2.99	-0.39	-0.21
Russia	1.30	-0.01	-0.79	-0.51
Rest of Europe	-0.01	0.93	-0.58	-0.33
Middle E. & N. Africa	0.01	0.24	-0.08	-0.17
Sub Saharan Africa	-0.48	3.06	-0.28	-2.30
Oceania	-0.01	0.28	-0.29	0.02
World	-2.06	13.13	-3.41	-7.66
Total Biofuel Regions	-2.85	6.04	-0.55	-2.63
Total Non- Biofuel Regions	0.80	7.09	-2.85	-5.03

Table 8. Impacts of US and EU biofuel mandates designed for 2015 on trade volumes of some commodities ($US million at constant 2006 fob prices)

Description	US	EU27	Brazil	Others	World
Change in exports:					
Coarse grains	-567.1	-179.5	-112.8	179.4	-680.0
Oilseeds	993.8	-103.2	609.6	2591.2	4091.4
Crude and refined vegetable oils	80.5	324.0	-99.1	816.5	1121.9
Livestock and processed livestock	-123.0	-504.5	-672.5	608.0	-692.0
Change in imports:					
Coarse grains	-71.2	4.7	-198.5	-415.0	-680.0
Oilseeds	33.3	4336.3	22.8	-301.0	4091.4
Crude and refined vegetable oils	59.1	1203.1	7.6	-148.0	1121.9
Livestock and processed livestock	-23.8	-40.1	42.3	-670.4	-692.0
Change in net exports					
Coarse grains	-495.9	-184.2	85.7	594.4	0.0
Oilseeds	960.6	-4439.5	586.7	2892.2	0.0
Crude and refined vegetable oils	21.3	-879.1	-106.7	964.5	0.0
Livestock and processed livestock	-99.2	-464.4	-714.8	1278.4	0.0

Table 9. Impacts of US and EU biofuel mandates designed for 2015 on the trade balances (values are in $US million)

Description	US	EU27	Brazil	Others
Agriculture products	1038.9	-9607.3	445.9	7566.6
Livestock and processed livestock	-63.5	-398.6	-618.4	639.5
All food products	200.8	-33.1	-883.9	478.9
Animal feeds (other than crops)	337.0	-114.0	-96.0	-1904.7
Other goods and services	2287.7	8283.7	901.3	-11472.7
Total	3800.8	-1869.3	-251.1	-1680.4

Table 10. Welfare impacts of US and EU biofuel mandates designed for 2015 in terms of Equivalent Variation (EVs are in $US million)

Regions	Alocative Efficiency Effect	Terms of Trade Effect	Saving-Investment Relative Price Effect	Total
USA	-14485	5962	984	-7539
CAN	131	-166	-72	-107
BRAZIL	531	3736	73	4340
JAPAN	824	1782	-215	2391
CHINA & Hong Kong	-183	438	-244	11
INDIA	227	1002	-17	1212
C. & Caribbean America	-79	-913	9	-983
S. & Other America	3	-1156	-26	-1179
East Asia	109	1316	-128	1297
Malaysia & Indonesia	-7	-30	-152	-189
Rest of South East Asia	9	788	0	797
Rest of South Asia	6	218	8	232
EU27	-23053	3646	-204	-19611
Russia	-48	-2476	8	-2516
Rest of Europe	-10	-1607	-48	-1664
Middle E. & N. Africa	-735	-11727	46	-12416
Sub Saharan Africa	-100	-1517	-13	-1630
Oceania	76	608	-11	673
Total	-36784	-96	-1	-36881
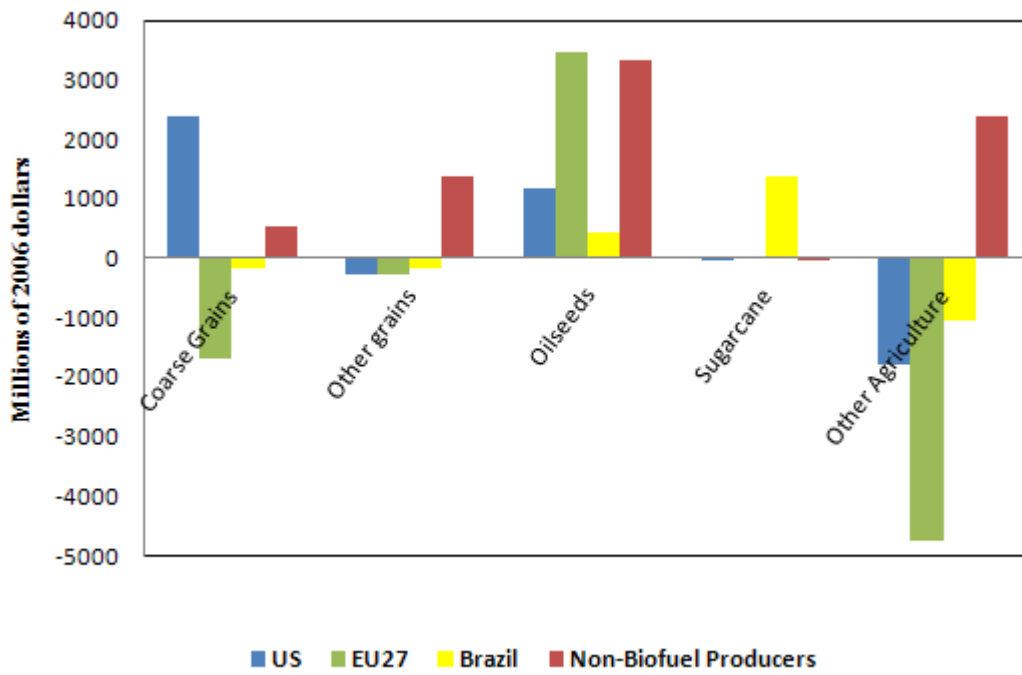
Figure 1. Changes in agricultural outputs due to biofuel mandates designed for 2015
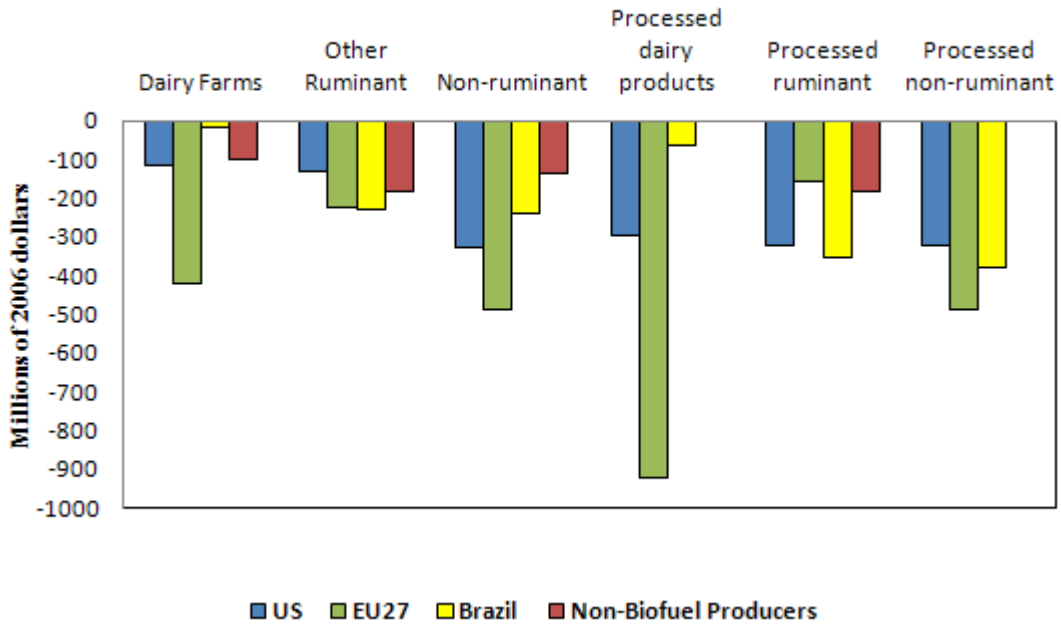
Figure 2. Changes in livestock outputs due to biofuel mandates designed for 2015
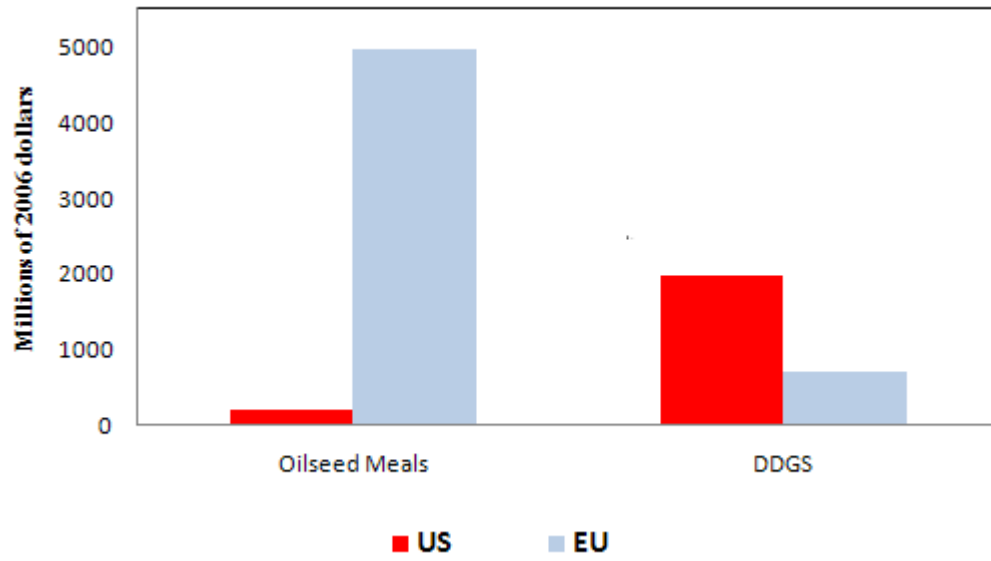
Figure 3. Changes in oilseed meals and DDGS outputs due to biofuel mandates designed for 2015
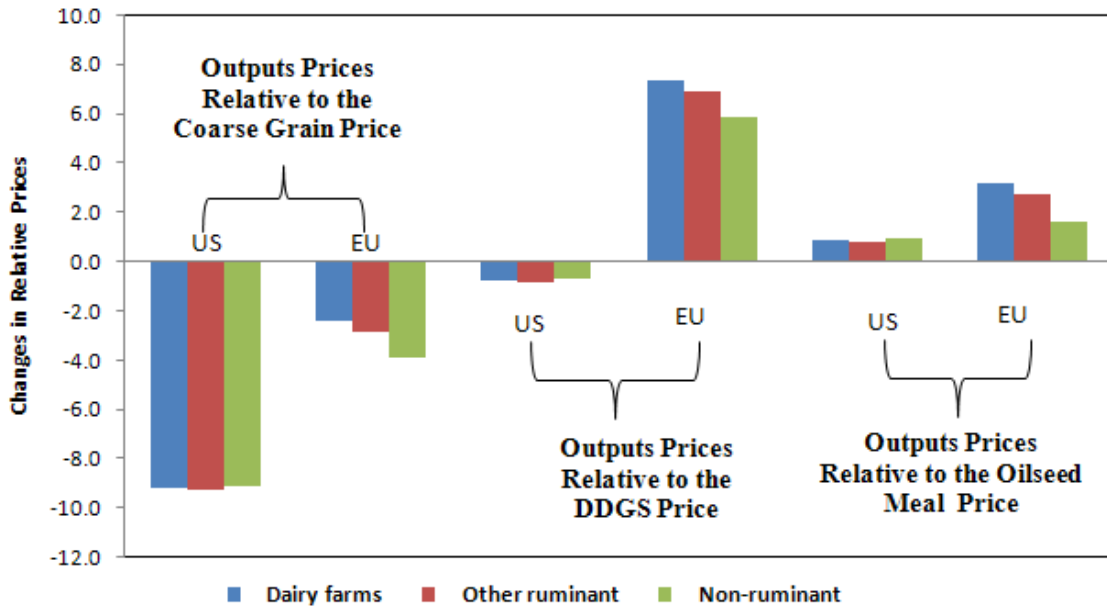
Figure 4. Changes in output prices for livestock industries relative to the prices of coarse grains and DDGS due to EU and US biofuel mandates designed for 2015 (%)
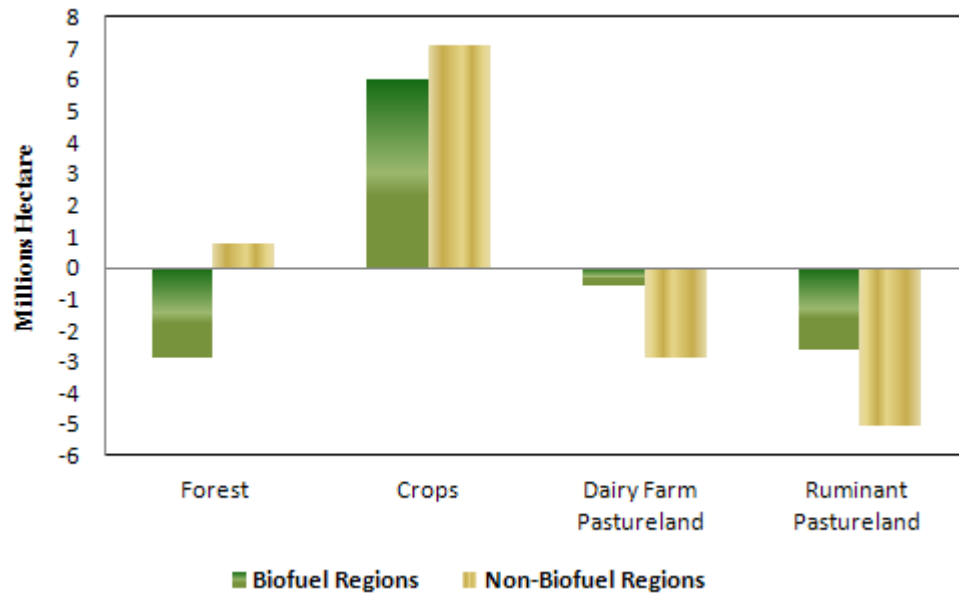
Figure 5. Land cover changes due to biofuel mandates designed for 2015
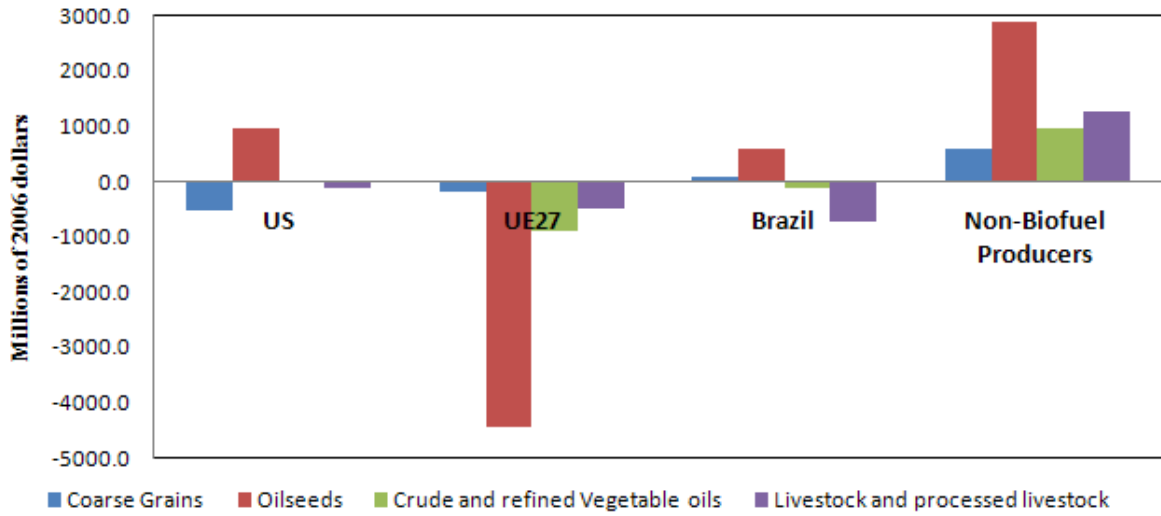
Figure 6. Changes in net exports of selected products due to biofuel mandates for 2015
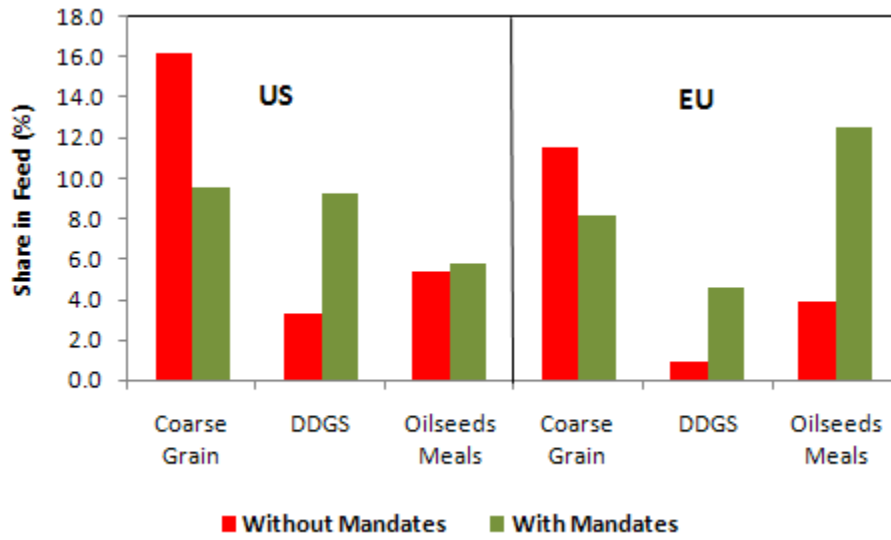
Figure 7. Shares of coarse grains, DDGs, and oilseeds meals in animal feed rations without and with biofuel mandates designed for 2015 (Dairy farms industry)
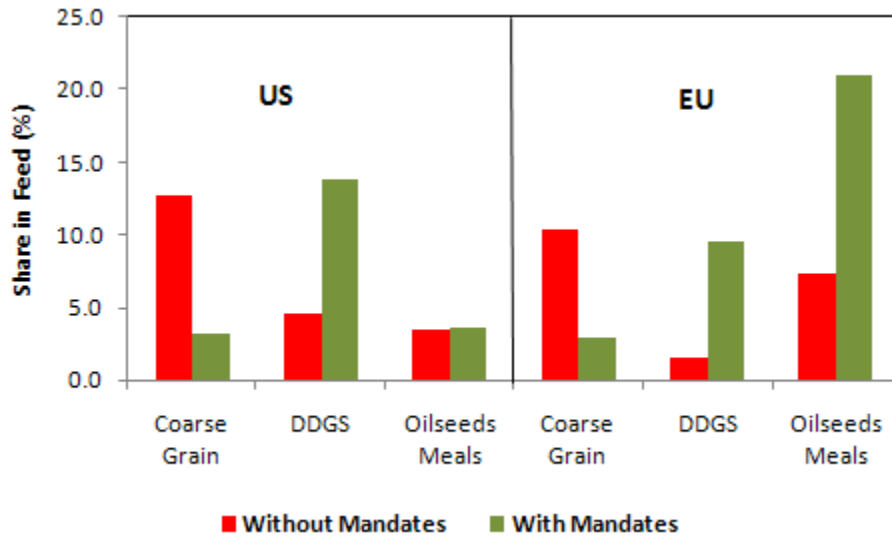
Figure 8. Shares of coarse grains, DDGs, and oilseeds meals in animal feed rations without and with biofuel mandates designed for 2015 (Ruminant meats industry)
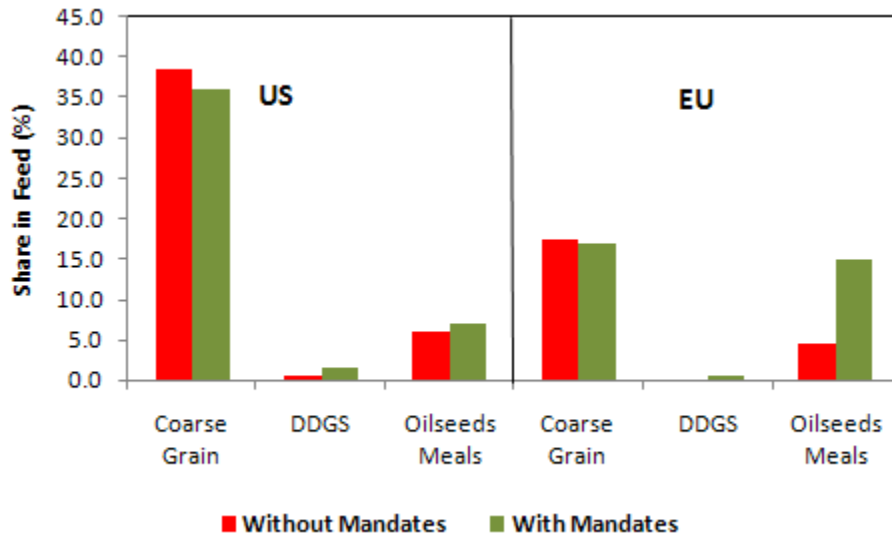
Figure 9. Shares of coarse grains, DDGs, and oilseeds meals in animal feed rations without and with biofuel mandates designed for 2015 (Non-ruminant industry)

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Appendix A
Lists of Commodities, Industries, and Regions

Table A1. List of industries and commodities in the new model

Industry name	Commodity name	Description	Corresponding Name in the GTAP_BIOB
CrGrains	CrGrains	Cereal grains	Gro
OthGrains	OthGrains	Other Grains	pdr, wht
Oilseeds	Oilseeds	Oil seeds	Osd
OthAgri	OthAgri	Other agriculture goods	ocr, pfb, v_f
Sugarcane	Sugarcane	Sugar cane and sugar beet	c-b
DairyFarms	DairyFarms	Dairy Products	Rmk
CattleRum	CattleRum	Cattle & ruminant meat production	Ctl
NonRum	Non-Rum	Non-ruminant meat production	oap, wol
ProcDairy	ProcDairy	Processed dairy products	Mil
ProcRum	ProcRum	Processed ruminant meat production	Cmt
ProcNonRum	ProcNonRum	Processed non-ruminant meat production	Omt
Forestry	Forestry	Forestry	Frs
Cveg_Oil	Cveg_Oil	Crude vegetable oil	A portion of vol
	VOBP	Oil meals	A portion of vol
Rveg_Oil	Rveg_Oil	Refined vegetable oil	A portion of vol
Bev_Sug_Pri	Bev_Sug_Pri	Beverages, tobacco, sugar, and processed rice	b_t, pcr, sgr
Proc_Food	Proc_Food	Processed food products	A portion of ofd
Proc_Feed	Proc_Feed	Processed animal feed products	A portion of ofd
OthPrimSect	OthPrimSect	Other Primary products	fsh, omn
Coal	Coal	Coal	Coa
Oil	Oil	Crude Oil	Oil
Gas	Gas	Natural gas	gas, gdt
Oil_Pcts	Oil_Pcts	Petroleum and coal products	p-c
Electricity	Electricity	Electricity	Ely
En_Int_Ind	En_Int_Ind	Energy intensive Industries	crpn, i_s, nfm
Oth_Ind_Se	Oth_Ind_Se	Other industry and services	crpn, i_s, nfm, atp, cmn, cns, dwe, ele, fmp, isr, lea, lum, mvh, nmm, obs, ofi, ome, omf, osg, otn, otp, ppp, ros, tex, trd, wap, wtp, wtr
EthanolC	Ethanol1	Ethanol produced from grains	
	DDGS	Dried Distillers Grains with Solubles	
Ethanol2	Ethanol2	Ethanol produced from sugarcane	
Biodiesel	Biodiesel	Biodiesel produced from vegetable oil	

Table A2. Regions and their members

Region	Description	Corresponding Countries in GTAP
USA	United States	usa
CAN	Canada	can
BRAZIL	Brazil	bra
JAPAN	Japan	jpn
CHIHKG	China and Hong Kong	chn, hkg
INDIA	India	ind
C_C_Amer	Central and Caribbean Americas	mex, xna, xca, xfa, xcb
S_o_Amer	South and Other Americas	col, per, ven, xap, arg, chl, ury, xsm
E_Asia	East Asia	kor, twn, xea
Mala_Indo	Malaysia and Indonesia	ind, mys
R_SE_Asia	Rest of South East Asia	phl, sgp, tha, vnm, xse
R_S_Asia	Rest of South Asia	bgd, lka, xsa
EU27	European Union 27	aut, bel, bgr, cyp, cze, deu, dnk, esp, est, fin, fra, gbr, grc, hun, irl, ita, ltu, lux, lva, mlt, nld, pol, prt, rom, svk, svn, swe
Russia	Russia	rus
R_Europe	Rest of European Countries	che, xef, xer, alb, hrv, xsu, tur
MEAS_NAfr	Middle Eastern and North Africa	xme,mar, tun, xnf
S_S_AFR	Sub Saharan Africa	Bwa, zaf, xsc, mwi, moz, tza, zmb, zwe, xsd, mdg, uga, xss
Oceania	Oceania countries	aus, nzl, xoc

Appendix B

Feed Composites in Livestock Industries

Table B1. Composite of feed stuffs by region with and without US and EU mandates (dairy farms)

Description	USA	EU27	BRAZIL	JAPAN	CHINA & Hong Kong	INDIA	Central & Caribbean America	South & Other America	East Asia
With Mandates									
Coarse Grains	9.6	8.1	26.9	14.1	24.4	0.3	12.8	23.5	2.4
Other crops	1.7	33.6	40.4	56.1	31.2	89.9	62.3	22.0	36.3
Feeds from processed livestock	0.1	1.5	0.1	0.0	0.2	0.0	0.3	1.5	0.7
Processed Feed	73.8	39.7	29.9	29.8	44.1	0.1	23.8	51.7	58.4
DDGS	9.2	4.5	0.0	0.0	0.0	0.0	0.6	0.8	0.2
Oilseeds meals	5.7	12.6	2.6	0.0	0.0	9.7	0.3	0.5	2.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Without Mandates									
Coarse Grains	16.2	11.5	26.9	14.8	24.4	0.3	12.9	23.7	2.5
Other crops	1.7	34.6	41.1	55.5	31.4	90.1	62.4	22.6	36.0
Feeds from processed livestock	0.1	1.5	0.1	0.0	0.2	0.0	0.3	1.4	0.7
Processed Feed	73.4	47.6	26.3	29.7	44.1	0.2	23.8	51.3	58.6
DDGS	3.3	0.9	0.0	0.0	0.0	0.0	0.4	0.5	0.2
Oilseeds meals	5.4	3.9	5.6	0.0	0.0	9.3	0.2	0.4	2.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Description	Malaysia & Indonesia	Rest of South East Asia	Rest of South Asia	Canada	Russia	Rest of Europe	Middle East & North Africa	Sub Saharan Africa	Oceania
				With Mandates					
Coarse Grains	0.5	10.9	1.2	14.3	16.9	13.8	11.8	7.8	3.3
Other crops	13.5	4.3	85.0	42.8	64.0	71.5	62.7	16.3	43.7
Feeds from processed livestock	0.0	0.2	2.5	0.3	13.8	0.7	13.5	1.7	4.2
Processed Feed	84.9	84.6	3.3	42.6	4.4	13.8	11.4	70.4	48.4
DDGS	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.4	0.0
Oilseeds meals	1.0	0.0	8.0	0.0	0.9	0.3	0.3	1.4	0.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
				Without Mandates					
Coarse Grains	0.5	11.0	1.3	14.4	16.9	13.7	12.0	8.0	3.3
Other crops	13.6	4.3	85.0	43.3	64.3	71.7	62.8	16.5	44.2
Feeds from processed livestock	0.0	0.2	2.4	0.3	13.5	0.7	13.2	1.6	4.2
Processed Feed	85.0	84.5	3.3	41.9	4.3	13.7	11.5	70.6	48.2
DDGS	0.0	0.0	0.0	0.1	0.0	0.0	0.2	2.3	0.0
Oilseeds meals	0.9	0.0	8.0	0.0	1.0	0.2	0.3	1.0	0.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table B2. Composite of feed stuffs by region with and without US and EU mandates (ruminant)

Description	USA	EU27	BRAZIL	JAPAN	CHINA & Hong Kong	INDIA	Central & Caribbean America	South & Other America	East Asia
With Mandates									
Coarse Grains	3.2	2.9	46.3	40.4	8.1	1.7	13.4	13.4	9.1
Other crops	2.3	22.1	16.7	26.9	71.9	92.4	61.4	10.0	38.5
Feeds from processed livestock	0.7	6.3	0.1	0.0	0.1	0.0	0.8	40.9	0.0
Processed Feed	76.4	38.2	34.0	32.6	19.9	0.0	22.6	33.4	51.9
DDGS	13.8	9.5	0.0	0.0	0.0	0.0	0.9	1.0	0.2
Oilseeds meals	3.6	21.0	2.9	0.0	0.0	5.8	0.9	1.3	0.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Without Mandates									
Coarse Grains	12.7	10.4	46.7	41.8	8.0	1.7	13.8	14.0	9.5
Other crops	2.4	23.1	16.8	26.2	72.1	92.6	61.5	10.2	38.1
Feeds from processed livestock	0.7	6.2	0.1	0.0	0.1	0.0	0.7	40.3	0.0
Processed Feed	76.3	51.6	30.1	32.0	19.8	0.1	22.8	33.8	52.1
DDGS	4.5	1.5	0.0	0.0	0.0	0.0	0.5	0.6	0.1
Oilseeds meals	3.4	7.3	6.3	0.0	0.0	5.5	0.7	1.1	0.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table B2. Continued

Description	Malaysia & Indonesia	Rest of South East Asia	Rest of South Asia	Canada	Russia	Rest of Europe	Middle East & North Africa	Sub Saharan Africa	Oceania
					With Mandates				
Coarse Grains	1.5	34.6	1.0	18.3	17.7	16.9	20.5	5.7	7.6
Other crops	17.1	17.0	78.4	56.2	55.8	59.7	68.1	36.6	72.2
Feeds from processed livestock	0.0	0.3	0.0	0.4	9.6	3.7	1.3	5.8	1.7
Processed Feed	80.4	47.5	11.4	25.1	15.1	18.4	8.2	45.0	17.9
DDGS	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.0
Oilseeds meals	0.9	0.6	9.2	0.0	1.8	1.3	1.7	6.6	0.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
					Without Mandates				
Coarse Grains	1.6	34.7	1.0	18.3	17.7	16.7	20.9	5.7	7.7
Other crops	17.3	17.1	78.4	56.7	56.0	60.1	67.9	36.9	72.4
Feeds from processed livestock	0.0	0.3	0.0	0.4	9.5	3.7	1.2	5.7	1.6
Processed Feed	80.4	47.7	11.3	24.5	14.8	18.4	8.4	46.7	18.0
DDGS	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.4	0.0
Oilseeds meals	0.8	0.2	9.3	0.0	1.9	1.2	1.4	4.6	0.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table B3. Composite of feed stuffs by region with and without US and EU mandates (non-ruminant)

Description	USA	EU27	BRAZIL	JAPAN	CHINA & Hong Kong	INDIA	Central & Caribbean America	South & Other America	East Asia
					With Mandates				
Coarse Grains	36.0	17.0	42.5	1.7	1.4	6.7	10.7	21.1	1.8
Other crops	1.4	18.7	21.7	18.0	53.7	78.8	57.0	23.2	15.8
Feeds from processed livestock	3.4	2.2	0.2	0.0	0.1	0.0	0.4	1.9	0.0
Processed Feed	50.9	46.6	32.9	80.3	44.8	0.9	31.4	52.5	78.2
DDGS	1.4	0.4	0.0	0.0	0.0	0.0	0.2	0.2	0.0
Oilseeds meals	6.9	15.0	2.7	0.0	0.0	13.6	0.3	1.0	4.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
					Without Mandates				
Coarse Grains	38.7	17.4	42.8	1.8	1.4	6.7	10.7	21.2	1.8
Other crops	1.4	19.4	21.9	17.8	53.9	79.1	57.1	23.7	15.7
Feeds from processed livestock	3.3	2.2	0.2	0.0	0.1	0.0	0.3	1.8	0.0
Processed Feed	49.7	56.1	29.1	80.4	44.6	3.0	31.5	52.2	78.2
DDGS	0.7	0.2	0.0	0.0	0.0	0.0	0.2	0.2	0.0
Oilseeds meals	6.2	4.6	6.0	0.0	0.0	11.1	0.3	0.8	4.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Description	Malaysia & Indonesia	Rest of South East Asia	Rest of South Asia	Canada	Russia	Rest of Europe	Middle East & North Africa	Sub Saharan Africa	Oceania
With Mandates									
Coarse Grains	2.3	9.1	17.7	10.9	15.2	24.7	31.8	1.7	5.2
Other crops	8.9	16.7	70.5	30.3	50.8	45.4	49.0	11.8	17.8
Feeds from processed livestock	0.1	0.2	0.3	0.2	12.7	1.1	1.6	1.4	14.7
Processed Feed	84.8	73.8	4.1	58.5	20.2	28.2	16.0	78.9	62.1
DDGS	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0
Oilseeds meals	3.9	0.3	7.4	0.0	1.1	0.6	1.6	6.1	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Without Mandates									
Coarse Grains	2.3	9.2	17.7	11.1	15.2	24.6	32.2	1.7	5.3
Other crops	9.0	16.8	70.6	30.9	51.1	45.7	48.7	11.9	18.1
Feeds from processed livestock	0.1	0.2	0.3	0.2	12.6	1.1	1.5	1.4	14.5
Processed Feed	85.2	73.8	4.1	57.8	20.0	28.2	16.2	80.6	62.0
DDGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Oilseeds meals	3.4	0.1	7.4	0.0	1.2	0.6	1.3	4.2	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0