FACTOR MARKETS

Comparative Analysis of Factor Markets for Agriculture across the Member States

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Factor Markets in General Computable Equilibrium Models

ABSTRACT

One objective of *Computable general equilibrium* (*CGE*) models is the analysis of economy-wide effects of policy measures. The focus of the Factor Markets project is to analyse the functioning of factor markets for agriculture in the EU-27, including the Candidate Countries. While agricultural and food markets are fully integrated in a European single market, subject to an EU-wide common policy, the Common Agricultural Policy (CAP), this is not the case for the agricultural factor markets capital, labour and land. There are partly serious differences with regard to member state regulations and institutions affecting land, labour and capital markets. The presentation of this heterogeneity of factor markets amongst EU Member States have been implemented in the CGE models to improve model-based analyses of the CAP and other policy measures affecting agricultural production.

This final report comprises the outcome of a systematic extension and improvement of the Modular Applied GeNeral Equilibrium Tool (MAGNET) model starting from an overview of the current state of the art to represent factor markets in CGE models to a description of work on labour, land and capital in MAGNET.

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Factor Markets in General Computable Equilibrium Models

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1. Introduction

One objective of Computable general equilibrium (*CGE*) models is the analysis of economy-wide effects of policy measures. The focus of the Factor Markets project is to analyse the functioning of factor markets for agriculture in the EU-27, including the Candidate Countries. While agricultural and food markets are fully integrated in a European single market, subject to an EU-wide common policy, the Common Agricultural Policy (CAP), this is not the case for the agricultural factor markets capital, labour and land. There are partly serious differences with regard to member state regulations and institutions affecting land, labour and capital markets. This heterogeneity of factor markets causes different effects of the CAP.

To comprise the different structures of factor markets and the related policy framework in the EU-27 member states, the database and methodology of CGEs have to be adopted for analyzing the characteristics in each country. In this project, the MAGNET model will be extended via more detailed specification and a better implementation of agricultural factor markets. MAGNET is a version of the well-known GTAP model that adds a better representation of the agricultural sector and its factor markets. It includes all EU-27 countries plus the Candidate Countries Croatia and Turkey.

In the first part of this report an overview of the different ways in which factor markets are implemented in other existing CGE models will be given. Chapter 3 describes the initial or basic state of factor market modelling in the MAGNET model. Chapter 4, 5 and 6 contain the developments of a more detailed implementation of factor markets labour, land and capital in MAGNET. For labour markets the theoretical and empirical foundations of labour supply curves for the member and candidate states and their introduction into the MAGNET CGE model will be described in chapter 4. Chapter 5 handles with the land market. It shows an improved representation of the land market by including imperfectly substitutable types of land, a land use allocation structure and land supply function in MAGNET. The implementation of capital in MAGNET is described in chapter 6.

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2. Factor markets in selected CGE-Models - A general overview

From the multitude of CGE models, factor market modelling is reviewed here in six key global models: GTAP and its variants: GTAP-AGR, GTAP-E, GTAP-DYN and G-MIG, GLOBE, the LINKAGE model, at the World Bank, MIRAGE, MAGNET and WORLDSCAN[1]. Given the heavy data requirements needed for a global model, most of the models described here use the common GTAP core database. In addition, most models are descendants of the GTAP global CGE model.

The GTAP database includes the use of five factors of production[2] by firms in the production process: land, capital, skilled labour, unskilled labour and natural resources. Payments for the use of factors in the production process is the only source of income to factors and the income is distributed to the private household as the owner and supplier of factors and to the government in the form of direct tax payments via the regional household. There are no flows to domestically owned factors used overseas or foreign owned factors used domestically recorded in the standard database.

All firms use capital, skilled labour and unskilled labour; however land is only used by agricultural sectors and natural resources are only used by the forestry, fishing, coal, oil, gas and other minerals sectors. Capital is the only factor that is subject to depreciation.

2.1 Labour markets

Labour is classified as a mobile factor in the standard GTAP model. As such, labour is free to move between sectors in a country or region in response to changes in relative prices; which leads to an equalisation of the increase or decrease in the wage rate across all sectors. Two types of labour are included in the standard GTAP model; skilled labour and unskilled labour. Each type of labour has its own wage rate determined by the interaction of the supply of labour (usually exogenous) and the demand for labour as a factor of production. Skilled and unskilled labour are substitutable both for the other type of labour and the other factors of production in the formation of the value added composite which in turn is substitutable with composite (domestic and imported) intermediate goods in the production of the output of each sector.

[1] A short description of the models can be found in the appendix.

[2] Considered as non-tradable commodities and referred to as endowment commodities in the GTAP literature.

Table 1. Labour market features in global CGE model

Feature	GTAP	GTAP-AGR	GTAP-E	GTAP-DYN	G-MIG	MIRAGE	LINKAGE	GLOBE	WORLDSCAN
Skilled/ unskilled labour	X	X	X	X	X			X	X
Segmented markets (rural, urban)						X	X	X	
Unemployment	X	X	X	X			X	X	X
Farm/ off farm employment		X				X			
Wage differences farm / off farm		X							
Minimum wage						X	X		
Farm-owned (value-added) aggregate		X							
Mobility across sectors	X	X	X	X	X	X	X	X	X
International migration					X			X	X
Productivity differences of permanent and temporary labour					X				
Sector specific restriction					X			X	
Wage differences temporary workers / resident workers					X				
Complementarity between skilled labour and capital						X			
Wage bargaining							X		X
Activity specific restriction								X	
Labour supply and unemployment modelled endogenously								X	X

2.2 Capital markets

In standard GTAP, capital can move between industries within a region, but not between regions. The capital flow is immobile in the short run and mobile in the long run. In the standard GTAP-model investors are represented by a single agent, the global bank. The global bank receives savings from the households and invests this savings. Investments are represented by purchase a commodity named capital goods. Capital goods are not tradable. Because GTAP is a comparative static model, savings are incorporated as a fixed share of the households' utility function. At the global level investments and savings are equal, because there is no mechanism from capital markets to savings the amount of investments is the sum of savings in each region. Time preferences for investments or influences on the decision of saving levels are not captured. Therefore many adaptions have been made to model capital in CGE´s. An overview is given in the following table:

Table 2. Capital market features in global CGE model

Feature	GTAP	GTAP-AGR	GTAP-E	GTAP-DYN	G-MIG	MIRAGE	LINKAGE	GLOBE	WORLDSCAN
Mobile between regions				X	X	X	X	X	X
Mobile between sectors	X		X	X	X	X		X	X
Capital mobile between agriculture and non-agriculture		X						X	
Restricted mobility between sectors		X						X	
Farm household modeling		X							
Capital – Energy complementarity/substitutability			X					X	
Dynamic modeling of savings and investments				X	X	X			
Capital accumulation				X		X		X	
Regional capital stocks				X				X	
International assets and liabilities				X				X	
International investment and income flows				X	X			X	
Financial assets				X					
Intrinsic dynamic of physical and financial asset stocks				X					
Putty-clay hypothesis (immobility of installed capital)					X		X	X	
Partial mobility across sectors							X	X	
Semi-putty-clay hypothesis (partial immobility of installed capital)							X		
Vintage Capital – old /new capital							X		
Relation between savings and demography									X
Estimated savings function							X		
Exogenous savings rate	X								
Savings were derived from welfare maximisation and consumer decision									X
Regional savings and investment can diverge									X
Regional capital markets – imperfect capital mobility									X
Foreign direct investment incorporated through linkage of regional capital markets								X	X
Influence of transportation and transaction costs on capital flow									X

2.3 Land markets

The standard assumption of land markets in GTAP can be described by a sluggish sector specific factor land. Land – together with the factor 'natural resource' which is also included in the GTAP data base - is assumed to be immobile across domestic agricultural sectors. The agricultural sectors are the only land using sectors in the data base.[3] With the assumption of land as sluggish land prices differs across the land using sectors in agriculture. Similar to the standard presentation of land and capital land use is also presented only in value terms in the GTAP data base as a part of sectoral value added. Land use presented in physical units is not modelled in the standard version of GTAP.

Table 3. Land market features in global CGE model

Feature	GTAP	GTAP-AGR	GTAP-E	GTAP-DYN	G-MIG	MIRAGE	LINKAGE	GLOBE	WORLDSCAN
Only agricultural use	X	X	X	X	X			X	X
Imperfectly mobility between agricultural sectors	X	X	X	X	X	X	X	X	
Regions classification as land-constrained or not						X			
Land mobility across sectors						X	X		
Set aside						X			
Aggregate supply of land responds to changes of the real aggregate land price (logistic function)							X		
Allocation of land responds to the relative land prices across the activities (CET function)	X	X	X	X	X	X	X	X	

3. Factor Markets in MAGNET

3.1 The current state of factor market modelling in MAGNET

The Modular Applied GeNeral Equilibrium Tool (MAGNET, formerly LEITAP) is a global computable general equilibrium model that covers the whole world economy including factor markets. The model has been applied extensively to trade analyses, biofuel assessments and CAP analyses. This section outlines the current state of factor market modelling in MAGNET. Explicit reference is made to the modifications made to the model to better represent agricultural factor markets over and above the GTAP (Global Trade Analysis Project) model which forms the core of the model. The modelling of factor markets has been extended in MAGNET in five key ways; both by incorporating developments from other models such as GTAP-AGR, GTAP-E and GTAP-DYN and through unique innovations. The developments in the MAGNET model better capture the demand and supply of factors and the mobility of factors between sectors. The coverage of factor markets in the GTAP database is first addressed and then each factor market extension is discussed in detail, including the data requirements for the extension. Note that the modular nature of MAGNET allows the factor market in each region to be specified differently with features that pertain to that region.

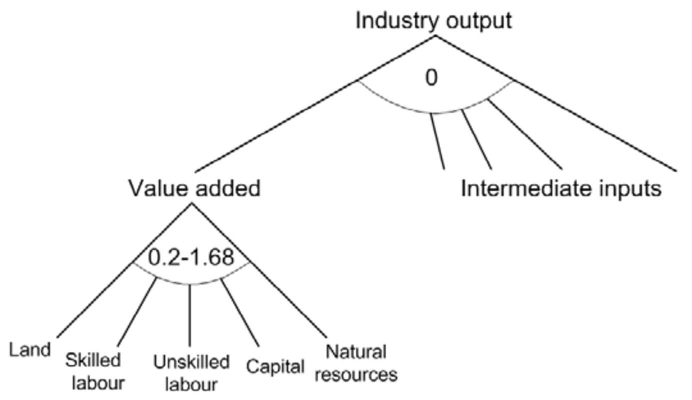
3.1.1 Flexible structure of factor demand

The demand for factor use by each sector is modelled in the standard GTAP model with a two-level CES production nest as shown in Figure 1. At the lower level, aggregate value added is formed through the optimal combination of factors which is then substitutable for all intermediate inputs at the top level of the production nest. Substitution between primary

[3] Land use in forestry is covered under the factor 'natural resource'.

factors is inelastic for the agricultural and extraction sectors (with values of 0.2-0.24) and higher among the other sectors (with values of 1.12-1.68). The elasticity of substitution between aggregate value added and intermediate inputs is set at zero in the standard GTAP version which reflects Leontief technology in which intermediate inputs and value added are combined in fixed proportions to produce the output good.

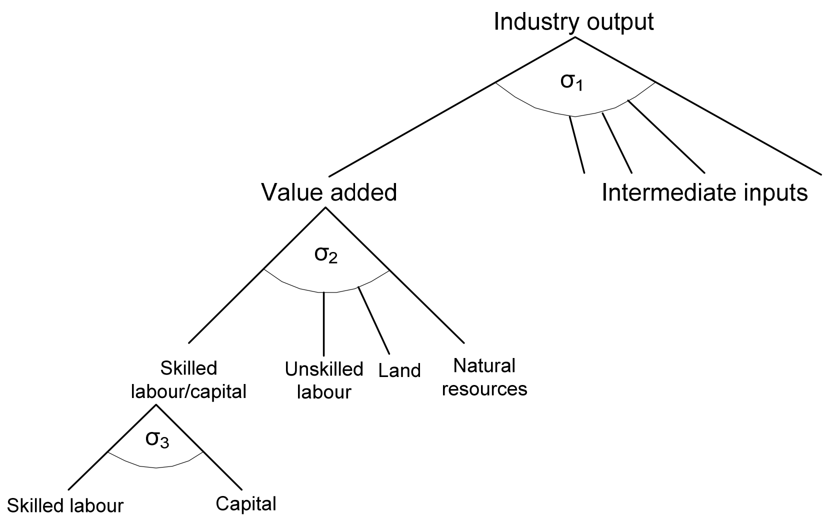
Figure 1. Factor demand in GTAP



Source: Own illustration.

The modelling of the production structure has been extending in two ways in MAGNET. Firstly by allowing substitution between aggregate value-added and intermediate inputs at the top level of the nest using the elasticities of substitution from the GTAP-AGR model. Secondly, in place of the two-level CES production structure in the standard GTAP model, the MAGNET model includes a fully flexible production structure in which the user can specify the production structure for each region and/or sector. Allowing for multiple levels of the production nest overcomes the disadvantage of a fixed production structure in which all pairs of inputs at the same level of the nest have the same degree of substitutability. It may be desirable for example to specify a different substitutability between capital and skilled labour to reflect their complementary (see Figure 2).

Figure 2. Example of factor demand in MAGNET



Source: Own illustration.

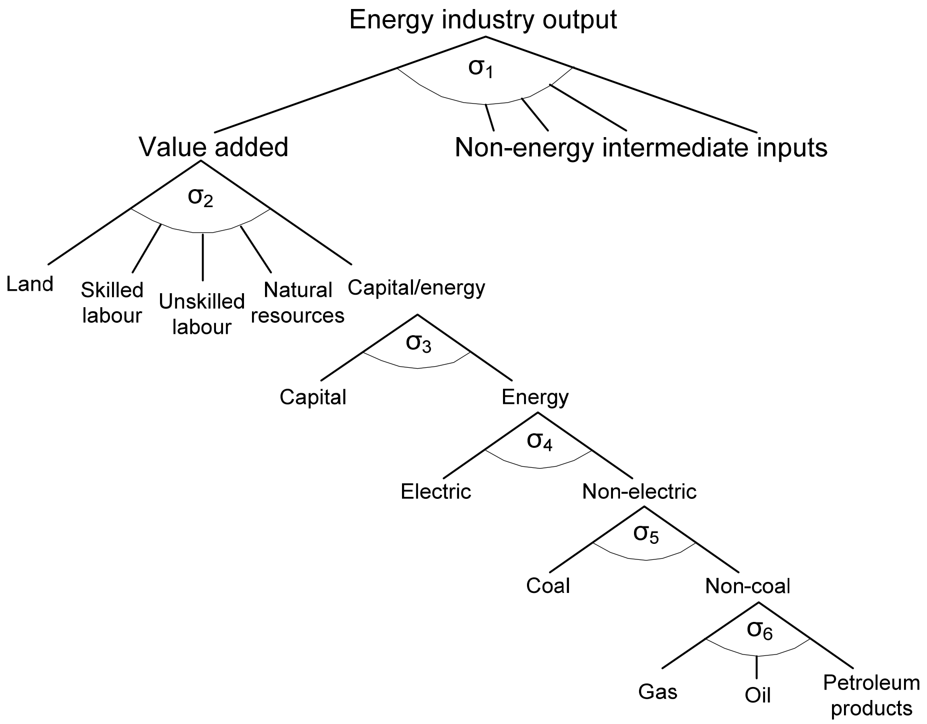
Furthermore, the flexible production structure in MAGNET also allows for factors to be directly substitutable with intermediate inputs. This may be desirable in scenarios of energy use where capital and energy may be viewed as directly substitutable. The introduction of direct substitution between capital and energy following the GTAP-E structure (Burniaux and Truong, 2002) is shown in Figure 3 Clearly, the advantage of the MAGNET structure of factor demand is its flexibility which allows the model to be tailored to each regions' characteristics and the research question. Such flexibility does however require more data; specifically the elasticities of substitution between inputs at all levels of the nest must be specified as part of the modelling process.

3.1.2 Land supply function

The supply of land, labour and natural resources is fixed in the standard static version of the GTAP model. Also, although the capital stock can grow through investment (net of depreciation), the static nature of the model means that new capital is not brought into use until the next period and therefore the capital stock is also fixed. Unemployment can be introduced into the model by fixing the nominal wage rate and allowing the quantity of labour supplied to change.

The primary development of MAGNET in terms of factor supply is the introduction of a land supply function which allows for more land to be used in agriculture at a higher rental rate up to the maximum amount of land available. The positive relationship between land supply and the land price is based on the assumption that additional land will be more costly to use as either farmers have to use land that is less productive and therefore have higher associated costs or it requires converting land from other uses into land suitable for agriculture, again at higher cost.

Figure 3. Further example of factor demand in MAGNET

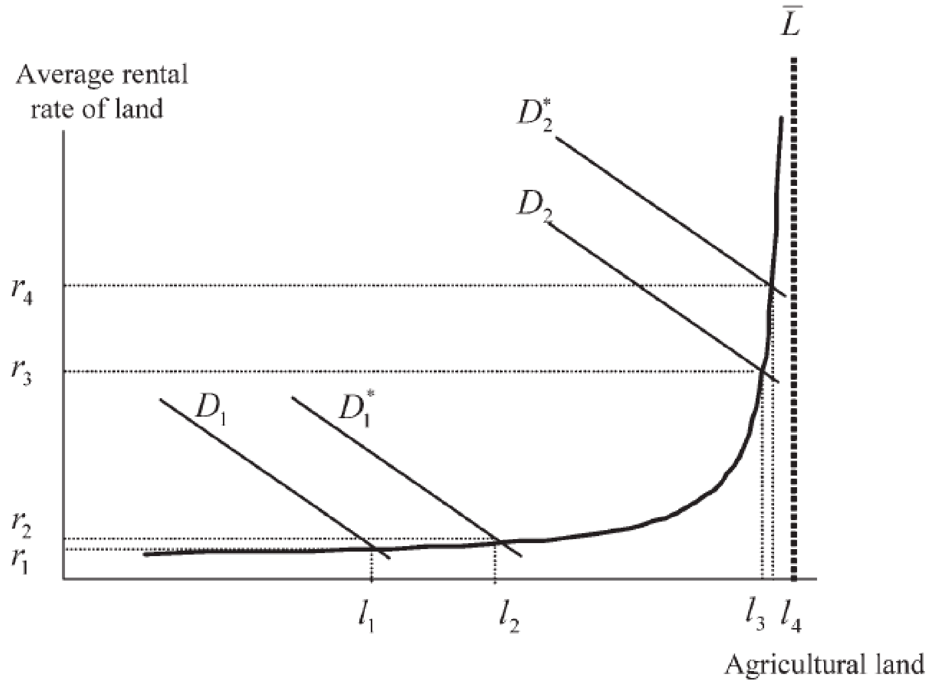


Source: Own illustration.

The relationship between the average rental rate of land and land supply is specified for each region using three pieces of information: current land use in km^2, the maximum amount of land available for use in km^2 and the price elasticity of land supply. Data on current land use and the maximum available land in each region are taken from work done with the IMAGE model based on biophysical data (Eickhout et al., 2007).

An example of the land supply curve is shown in Figure 4, where l_1 is the current land use, $\bar{L}$ is the total land available and forms the asymptote of the function, and the slope of the curve is determined by the price elasticity of land supply. Clearly the proximity of current land supply to maximum land supply has important implications for how changes in demand affect the land price. In land abundant countries such as Brazil, there is still a large amount of land available so an increase in demand (from D_1 to D_1^*) can be accommodated with only small increases in rental rates. In contrast, land constrained regions such as the EU and Japan are already using an amount of land close to the maximum available. A similar increase in demand (from D_2 to D_2^*) can only be met if the rental rate increases a great deal to bring remaining land into the market.

Figure 4. Land supply curve in MAGNET



Source: Banse et al. (2008), p. 125.

Allowing for changes in land supply and rental rates is important when the policy in question will affect the demand for land. Regions that are land abundant will be able to meet the demand for extra land at lower prices than land constrained regions which in turn affects the regions' competitiveness.

3.1.3 Factor supply over time

In addition to allowing factor supplies to change in response to changes in demand as in the case of the land supply function, the dynamic nature of the MAGNET model also allows the supply of factors to change over time. Growth in the labour supply is assumed to follow USDA population projections. Capital is assumed to grow in line with baseline GDP growth also from USDA based on World Bank projections[4] to maintain a constant capital-output ratio. The new capital goods are assumed to be created according to a fixed combination of inputs that varies by region and typically includes large shares of construction and machinery and equipment complemented with electricity, trade and business service inputs. The capital good is created from both imported and domestically sourced inputs upon which sales taxes

4 http://www.ers.usda.gov/Data/Macroeconomics/#BaselineMacroTables

are levied, but without the use of factors. The factor use associated with investment is assumed to already be embodied in the inputs used; there is no extra value added in the creation of the investment good. Investment in the capital good affects the demand for these inputs but does not affect the size of the capital stock as the model is only run for one period. Investment in new capital goods is driven by available savings in the GTAP model.

Factor supply can change through the quantity supplied or the quality supplied where the latter is affected by technological change. Future economic growth is driven by technological change but the assumption about how that change is distributed among inputs is down to the user in MAGNET. The current set up of the model assumes that agriculture grows twice as fast as the service sector and that manufacturing grows 2.65 times as fast. This growth is distributed to bring about labour-saving technical change and some input-saving technical change thereby improving the quality of the inputs and their effective supply. Land productivity is altered in the baseline in line with FAO projections which indicate increasing land productivity in all regions to 2030.

3.1.4 Segmented agricultural and non-agricultural factor markets

Factor mobility refers to the speed in which factors can move between sectors in response to changes in relative returns. The modelling of factor mobility has been extended along two dimensions in the MAGNET model. Firstly, through the introduction of segmented labour and capital markets in agriculture and non-agriculture and secondly, through the modelling of land transformation between uses in agriculture which is discussed below.

Two types of factors are identified in the GTAP model: perfectly mobile factors that can switch freely between sectors leading to an equalisation in the rate of return, and sluggish factors that adjust more slowly leading to different sectoral returns. The user can define which factors are considered to be sluggish and which are perfectly mobile. The transformation of sluggish factors between uses in different sectors is governed by a CET function where the speed of adjustment to changes in relative returns, depends upon the elasticity of transformation. Higher absolute levels of transformation elasticity allow sluggish factors to be released more quickly in response to changes in relative returns. In the standard setup of the GTAP model, land and natural resources are deemed to be sluggish factors with a transformation elasticity of -1 for land and -0.001 for natural resources. Land is therefore more mobile than natural resources but less mobile than labour and capital.

Keeney and Hertel (2005) motivate the introduction of segmented factor markets by four observations: the role of off-farm factor mobility in farm incomes, co-movements in farm and non-farm wages, steady off-farm migration and persistent rural-urban wage differentials (Keeney and Hertel, 2005, p6-7). The MAGNET model allows for three types of factor markets for labour and capital: unsegmented (GTAP), segmented with movement between the markets determined by a CET function (following the GTAP-AGR model) or segmented markets with dynamic factor markets (where factors migrate between sectors in response to changes in relative returns). Segmented factor markets imply different factor prices in each market and separate market clearing conditions. Currently there are two markets in the segmented factor market module: agriculture and non-agriculture.

The segmented factor markets module links to the rest of the model through endowment prices and the factor market clearing condition. The endowment price is defined as the market price for the endowment plus any taxes on factor use. As there are two markets for factors in the segmented market (agriculture and non-agriculture), the factor price is defined as the agriculture market price plus taxes in the agricultural market and as the non-agriculture market price plus taxes for the non-agricultural market. The market price for each factor is therefore a weighted average of the agricultural market price and the non-agricultural market price. Labour and capital are freely mobile within each sector leading to a single price in the agricultural factor market and in the non-agricultural factor market.

The market clearing condition for the factor market in GTAP is replaced with two market clearing conditions in the segmented factor market module; one for agriculture and one for non-agriculture. The market supply of each factor is therefore equal to the demand for each factor across all industries *within each market*. Total supply of each factor is the sum of the supply of each factor in the agricultural and non-agricultural factor markets.

Although there are two distinct markets for mobile factors in the segmented factor markets module, labour and capital can still move between the two markets. Indeed, extra labour or capital needed in the non-agricultural sector must be pulled from the agricultural sector and vice versa. The movement of factors between agricultural and non-agricultural markets is determined either by changes in relative prices and an elasticity of transformation (CET function) or by changes in relative prices and a speed of adjustment parameter (dynamic factor markets).

In the absence of available data on the underlying barriers to factor mobility, Keeney and Hertel (2005) introduce a CET function in GTAP-AGR to 'transform' farm labour into non-farm labour and farm capital into non-farm capital. This option in MAGNET follows the set up in GTAP-AGR and is documented in Keeney & Hertel (2005). The transformation of factors between the two markets is governed by the elasticity of transformation. Note that the elasticity of transformation within each market is endowment and region specific but not market specific; so the same elasticities apply in both markets. The transformation elasticity is set at -1 for all factors and regions in the first instance.

The dynamic factor market module offers a different way of determining the movement of factors from agriculture to non-agriculture. The module includes an agricultural employment equation,

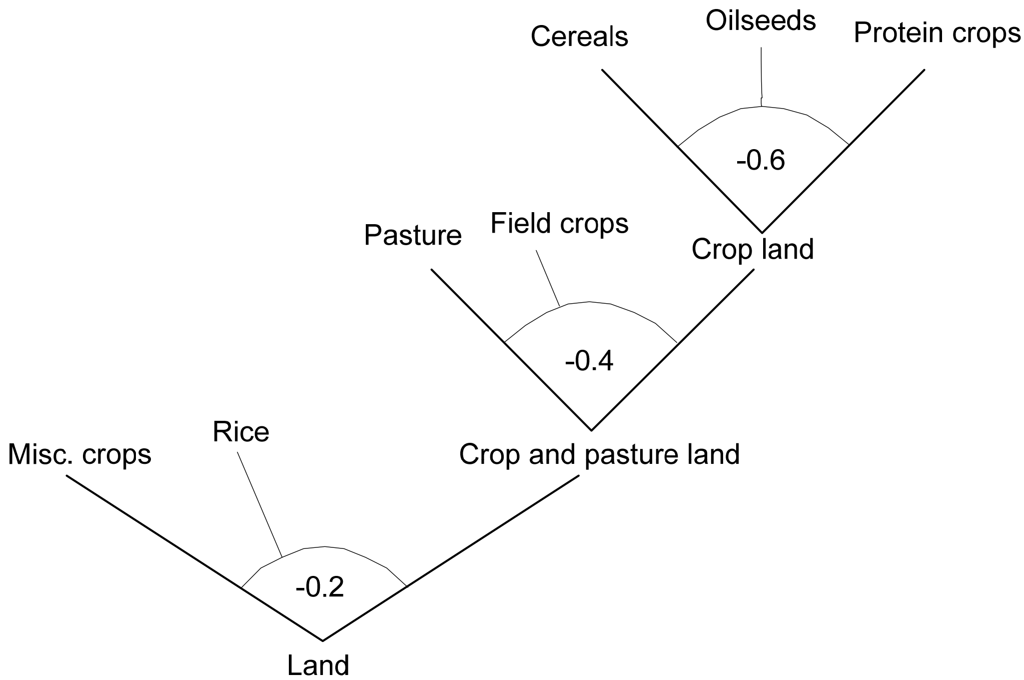
$$\text{qoagr(i,r)= DYNAGNAG(i,r)} * \left(\frac{PAENDWM_{i,r}}{PNAENDWM_{i,r}} - 1\right) \text{*100*time}$$

where the percentage change in the quantity of labour or capital (i) used in agriculture (qoagr) in each region (r) is determined by the relative wage between the two sectors, the time period and a speed of adjustment parameter (DYNAGNAG). The initial difference between the agricultural and non-agricultural wage levels is taken as indicative of the reservation wage in agriculture. A value of 0.07 is used for the speed of adjustment between the two markets based on econometric estimation. A full description of the estimation of the agricultural employment equation can be found in Tabeau & Woltjer (2010).

3.1.5 Land allocation

Land allocation is the second of the MAGNET factor market extensions that pertain to factor mobility. The standard GTAP model identifies only one form of land and allows for that land to be sluggishly transformed between the agricultural sectors that use the land in response to changes in relative prices. The single tier function used to transform land between different sectors in the GTAP model implies that the degree of transformability is the same between land used in all sectors. In reality, land used to grow crops may be more easily transformed between some land uses than others. For example, transforming the use of land between different crop types is likely to be easier than the transformation from arable land to grazing land. The MAGNET model captures these differences in transformability of land between uses using a three tier Constant Elasticity of Transformation (CET) function following Huang et al. (2004).

Figure 5. Land allocation in the MAGNET model



Source: Own illustration.

The process governing land allocation in the MAGNET model is shown in Figure 5. The three-tiered CET structure allows the mobility of land between uses to vary according to how the land is used. Sectors that use land are grouped according to ease of transformability. Land used to grow cereals, oilseeds and protein crops is considered to be most easily transformable between the three uses with a transformation elasticity of -0.6. The aggregated land from these three uses is then transformable with field crop land and pasture land with a lower degree of transformability, -0.4. Finally, aggregate crop and pasture land is transformable into land used to grow rice and other crops (such as vegetables and orchard fruits) with the lowest degree of transformability, -0.2.

3.2 Extensions of factor market modelling in MAGNET

The description of work for the Factor Markets project specifies three types of extensions to factor market modelling. For each factor market, the specification, implementation and links to other models should be improved; where specification refers to demand, supply, mobility and substitutability and implementation refers to parameters and economic data that underlie the modelling of the factor market. The review of CGE models provides ample examples of how factor market modelling could be extended in MAGNET.

A range of possible extensions of factor market modelling in MAGNET are shown in Table 4. The specification of the capital market could be improved through the introduction of capital vintages, sector specific capital or allowing for different types of investment good. The latter would be interesting to better capture the impact of the wave of investment that accompanies new industries on the capital stock e.g. the development of an ethanol sector. The implementation of capital market modelling could be improved through better estimation of the substitution elasticities between capital and other factors as well as the parameters that govern the movement of capital between agricultural and non-agricultural markets.

Table 4. Possible extensions to factor market modelling in MAGNET

Factor market	Specification	Implementation	Links to other models
Capital	Vintages Putty-clay Industry-specific investment matrix	Improving elasticity of substitution with other factors. Improving transformation/migration parameter between segmented markets.	CAPRI, AgriPoliS
Labour	Unemployment Extend segmented market specification Minimum Wage Stickiness (union power) Human capital accumulation Migration Population dynamics	Improving elasticity of substitution with other factors. Improving transformation/migration parameter between segmented markets.	CAPRI
Land	Competition for land between all sectors Stickiness (regulatory environment)	Improving elasticity of substitution with other factors. Improving price elasticity of supply estimates.	CAPRI, farm level models

The specification of labour market modelling could be extended along many dimensions. An improved modelling of unemployment that incorporates a positive relationship between real wages and the supply of labour is desirable, as is the introduction of a minimum wage and capturing union power in European labour markets. Broader concerns such as migration, population dynamics and human capital accumulation, which are relevant to capturing the impact of the accession of new member states are also possible extensions for the modelling of factor markets. The implementation of labour markets in the model could be strengthened by improving the substitution elasticities between labour and other factors and the parameters governing the movement of labour between agricultural and non-agricultural markets. Finally, extending the segmented factor modelling to other sectors would also add flexibility to the model and improve the modelling of factor markets in the EU.

The specification of the land market could be extended to explicitly include the competition for land between all sectors of the economy: agricultural, forestry, manufacturing, services. Moreover, the speed at which land is brought into use could be adjusted with a stickiness parameter to reflect the different regulatory frameworks than govern land use in the member states and candidate countries. As with the capital and labour markets, improving the elasticities that govern the demand and supply of land would strengthen the modelling of the land market.

The final selection of improvements in factor market modelling in MAGNET will be taken in conjunction with the other members of the project as the extension work depends on the output of other work packages and their timetable for research. The impact of improving factor market modelling in MAGNET can be tested by comparing the results of the model with and without the extensions; with the expectation that the extended model will better capture the functioning of factor markets in the EU.

4. Labour

4.1 Labour supply curves for European Member and Candidate States

4.1.1 Background

The supply of labour endowments are often taken to be exogenous in CGE models; that is, determined outside the system by factors such as population growth. Whilst this may be true in the longer-term, in the shorter-term, the supply of labour to the market is influenced by the real wage. Higher wages increase the opportunity cost of being economically inactive and induce people to enter the labour force, while lower wages reduce the opportunity cost and lead to lower participation rates.

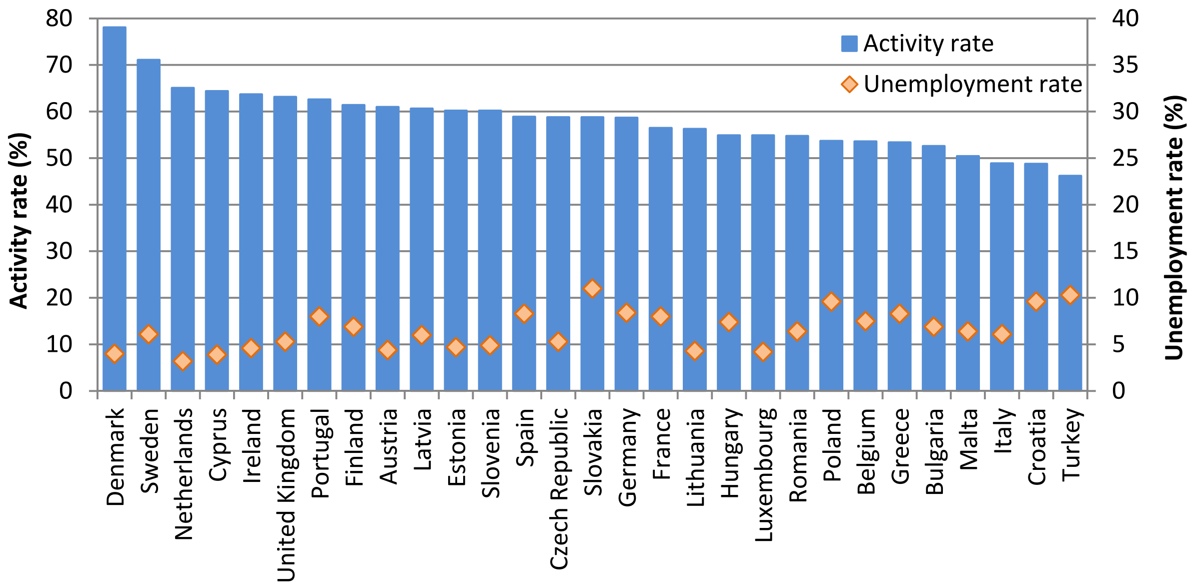
The relationship between real wages and the labour supply is often modelled at the extremes in CGE modelling: either by assuming that firms can employ more workers with no impact on the wage rate (to reflect spare capacity) or by assuming that all extra demand for labour is translated into higher wages (reflecting full employment of labour). Given the more nuanced relationship between wages and the labour supply as detailed above, a middle-way is required. A labour-supply curve offers such a way as it defines a relationship between real wages and employment based upon the proximity of current demand levels to the maximum amount of labour available within an economy.

This chapter presents the theoretical and empirical foundations of labour supply curves for the member and candidate states and their introduction into the MAGNET CGE model (formerly known as LEITAP). The paper begins with the theoretical specification of the labour supply curve and its properties. Labour supply curves are then derived for each country using real world data. An illustrative application of the new labour supply curves to CAP policy reform is introduced in section 4, followed by the results of the scenarios. The results of a sensitivity analysis of the parameters of the labour supply curve are also presented in the penultimate section with conclusions and future work outlined in section 5.

4.1.2 Extending the modelling of the labour supply

An initial inspection of labour data for the EU indicates heterogeneous labour markets. Activity and unemployment rates vary greatly across the member and candidate states as shown in Figure 6. The activity rate is defined as the proportion of the working age population that are in, or actively seeking, employment. Denmark has the highest activity rate in 2007 with 78.1% of the population economically active compared with only 46.2% in Turkey. There is also variation in the unemployment rate, defined as the share of the labour force not in employment, with only 3.2% of the Dutch over-15 population unemployed in 2007 but 11% of Slovenians. The two candidate countries included in the analysis, Croatia and Turkey have the two lowest activity rates and among the highest unemployment rates (9.6% and 10.3% respectively). There also appears to be a broadly negative relationship between the activity rate and the unemployment rate with countries that have the highest activity rates also having the lowest unemployment rates. The data are presented for 2007 as this is the base year of the MAGNET model and therefore the starting point for the general equilibrium analysis; clearly the European labour market position, particularly with regards to unemployment, will have changed in more recent years.

Figure 6. Activity and unemployment rates in the member and candidate states (2007)



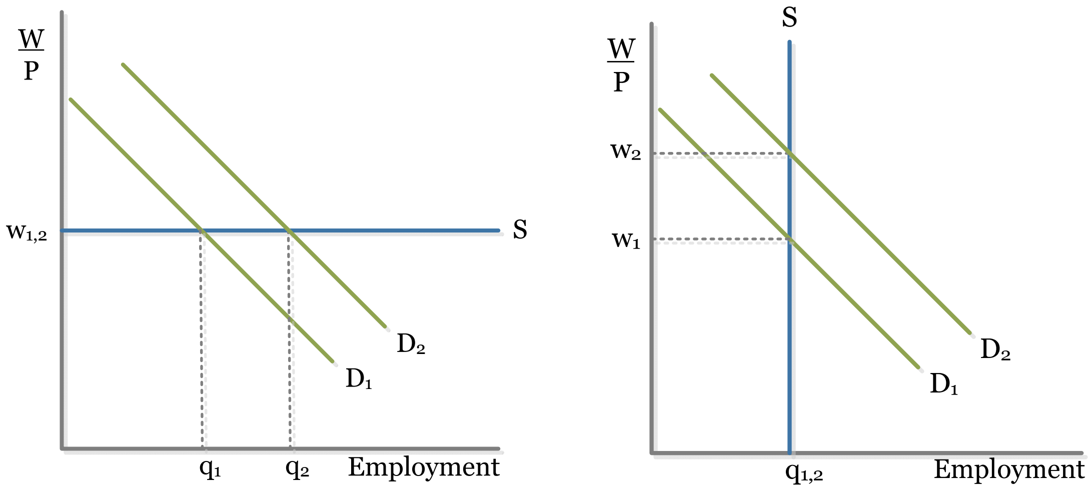
Source: ILO Labour Statistics.

As discussed in Shutes et al. (2012), the modelling of labour markets in the MAGNET model does not fully capture the heterogeneous nature of labour markets across the European member and candidate states. Shutes et al. provide an overview of possible extensions to labour market modelling in MAGNET drawn from developments in existing global and national CGE models to assist with the selection of an extension to be better capture labour market functioning across the EU. A labour supply curve is selected as an extension to labour market modelling in MAGNET because it allows the relationship between real wages and employment to be better depicted and captures the differences in this relationship across the member and candidate states. Moreover, such an extension is possible due to the relevant data being available through the Labour Force Surveys of the Europe Union countries.

4.1.2.1 Current specification

Typically, the relationship between the supply of labour and the real wage is modelled in one of two ways in CGE models. The two specifications operate at the extremes of labour market functioning; either by assuming an infinite supply of workers at a fixed wage or a fixed supply of workers with flexible wages. A visual representation of these two labour market specifications is given in Figure 7. The diagram on the left reflects an assumption of spare capacity in the labour market. A rightwards shift in the demand curve for labour under this assumption is met fully by an increase in the number of workers employed with no impact on the wage rate. The diagram on the right shows the opposite extreme in which all labour is fully employed and any additional demand is immediately translated into higher wages.

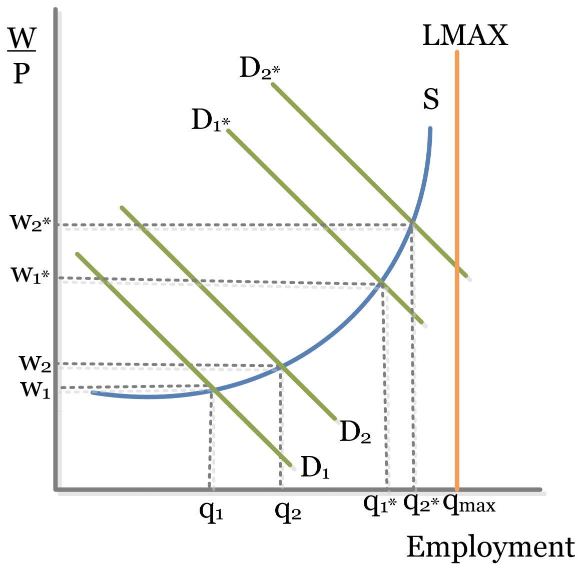
Figure 7. Labour market functioning in standard CGE models



4.1.2.2 Labour supply curve

The labour supply curve offers an intermediate choice in which increases in the demand for labour increase both the real wage and employment. The extent to which increases in demand are translated into wage increases depends upon the proximity of the current employment level to the total amount of available labour, reflecting the scarcity of labour. The functioning of a labour market with an upwards-sloping labour supply curve is shown in Figure 8. Countries whose current employment levels are relatively far from the maximum available amount of labour (LMAX) have labour markets with relatively shallow labour supply curves whilst countries with employment levels close to the maximum available amount of labour operate with steeper labour supply curves to reflect the scarcity of the labour factor.

Figure 8. Labour market functioning under an upwards-sloping labour supply curve



Defining the relationship between wages and labour supply in this way captures cross-country heterogeneity in the scarcity of labour. This enables the heterogeneous response to the same increase in demand to be captured. As shown in Figure 8, the same increase in demand has different effects for countries that are on the shallower part of the supply curve compared to those on the steeper part. For countries with relative spare capacity in labour, the increase in demand is met by an increase in supply with only a small effect on wages;

albeit more than under the strict spare capacity assumption shown in Figure 7. In contrast, the same increase in demand in countries with relatively scarce labour (nearing full employment) leads to only small increases in employment with large increases in the wage needed to attract the additional workers into the labour market.

The specification of a labour supply curve for inclusion in the MAGNET CGE model follows that of the land supply curve in van Meijl et al. (2006) and the labour supply curves for minority groups in Berrittella (2012):

$$LabourSupply = LMAX + \frac{\beta}{wage^{\alpha}} \quad (1)$$

where the $LabourSupply$ is the number of employed workers at the given wage rate, $LMAX$ is the total population of working age, β is a negative parameter calibrated on the current level of employment and wages and α is the power of the function. The equilibrium wage rate and employment determines the vertical position of the curve while the proximity of the equilibrium employment level to the maximum available amount of workers and the power of the function determine the shape of the curve.

4.1.2.3 Empirical labour supply curves for the European states

Empirically derived supply curves are presented in this section for the supply of unskilled labour in member states and two of the three candidate countries identified in the project outline: Croatia and Turkey[5]. The curves are derived from 2007 data as this is the starting year of the MAGNET model[6]. Four sets of data are required to derive the labour supply curve for each country: the labour supply by skill type (employment), the total population of working age by skill type, the real wage and the value of the power of the function (α). The value of the β parameter can then be calculated from these values. Employment data for the member and candidate states are extracted from the ILO LabourSta database[7] along with data on the population of working age. Real wages are calculated as the total value of payments to labour divided by the number of employees in each sector.

The specification of labour supply curves by skill type requires the employed and working-age populations to be identified by skill type. The ILO dataset includes employment by occupation group and labour force by occupation group data however both of these datasets are incomplete. In order to allocate all workers to either the skilled or unskilled category, the share of known skilled and unskilled labour in total employment is applied to all uncategorised workers[8]. The split of the total population of working age into skilled and unskilled workers in the total population of working age is taken from the occupational classification of the labour force. To the extent that the skills profile of the economically inactive differs from that of the economically active, this will be inaccurate. One area for further work is therefore to improve the skills profile of the economically inactive using information on educational attainment.

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[5] The Former Yugoslav Republic of Macedonia is part of a large aggregated region called Rest of Europe in the GTAP database that underlies the MAGNET model. Similarly the newer candidate countries, those accepted since the definition of the project, are also in aggregate regions; Serbia and Montenegro are also in the Rest of Europe region and Iceland is combined with Liechtenstein in the Rest of EFTA region.

[6] The early base year of the MAGNET model meant that the data could not be drawn from the project's labour market questionnaire which includes data for more recent years.

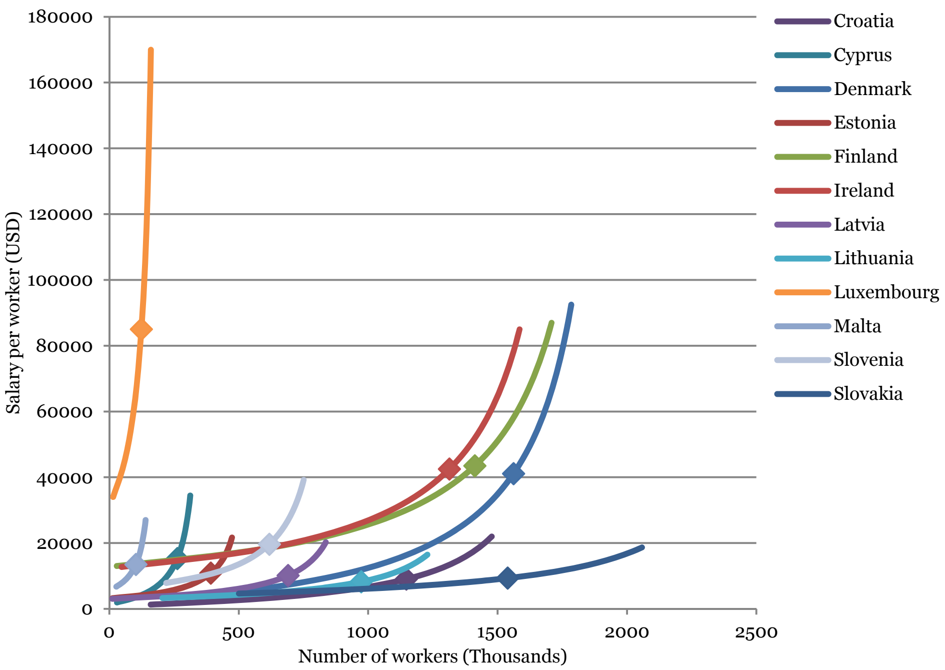
[7] Download date 2-5-2012.

[8] The skilled labour category used in the GTAP database corresponds to the ILO categories 1-3 containing managers and administrators, professionals, and para-professionals. The unskilled category corresponds to ILO categories 4-9 which includes trades-persons, clerks, salespersons and personal service workers, plant and machine operators and drivers, labourers and related workers, and farm workers (Dimaranan & Narayanan, 2007). The armed forces are currently allocated to the unskilled labour group although this could easily be revised if more data become available.

Calibrating the labour supply function of unskilled labour (1) with data for the member and candidate states yields labour supply curves for each country, grouped by size of country in Figure 9 to Figure 11[9]. Each curve is shown for a range of wage rates of between 30% of the equilibrium wage and twice the equilibrium wage. Plotting the curves in this way displays the portion of the curve around the 2007 equilibrium position. The number of people employed in 2007 in each country is indicated on the curves with a diamond-shaped marker. The set of supply curves are calibrated based on the assumption that the power of the function (α) is equal to one; an assumption that is retained for the illustrative scenarios in the following sections but varied in the sensitivity analysis in section 4.2.

Among the small European countries, the new member states have systematically lower wages than the EU15 countries. The vast majority of the smaller European countries are constrained in the supply of unskilled labour as shown by the strong upwards slope of the curves. The exceptions to this are Slovakia, Croatia and Lithuania which are on the flatter part of the curve indicating that only small increases in the wage would be needed to bring about an increase in the supply of unskilled workers. The clear outlier of this group of small countries is Luxembourg which has a high equilibrium wage but also near full employment of the working age population. Very large increases in wages are therefore needed to incite even small increases in the labour supply.

Figure 9. Labour supply curves for small European member and candidate states



A similar although less pronounced pattern can be observed in the empirical labour supply curves of medium-sized European countries as shown in Figure 10. The new member states have lower wages in 2007 than the medium-sized EU15 countries with the exception of Portugal. The curves of the new member states are also slightly shallower that those of the older member states. The equilibrium employment points of both Sweden and Austria are near the vertical portion of the labour supply curve suggesting that increased demand for unskilled labour in these countries will be mainly translated into higher labour prices. The candidate country of Croatia has one of the lowest average wage rates but slightly higher than Slovakian and Lithuanian member states.

9 Where 'small' countries have a working age population of less than 2.5 million, 'medium' countries have between 2.5 million and 5 million members of working age, and 'large' countries more than 5 million.

Figure 10. Labour supply curves for medium European member and candidate states

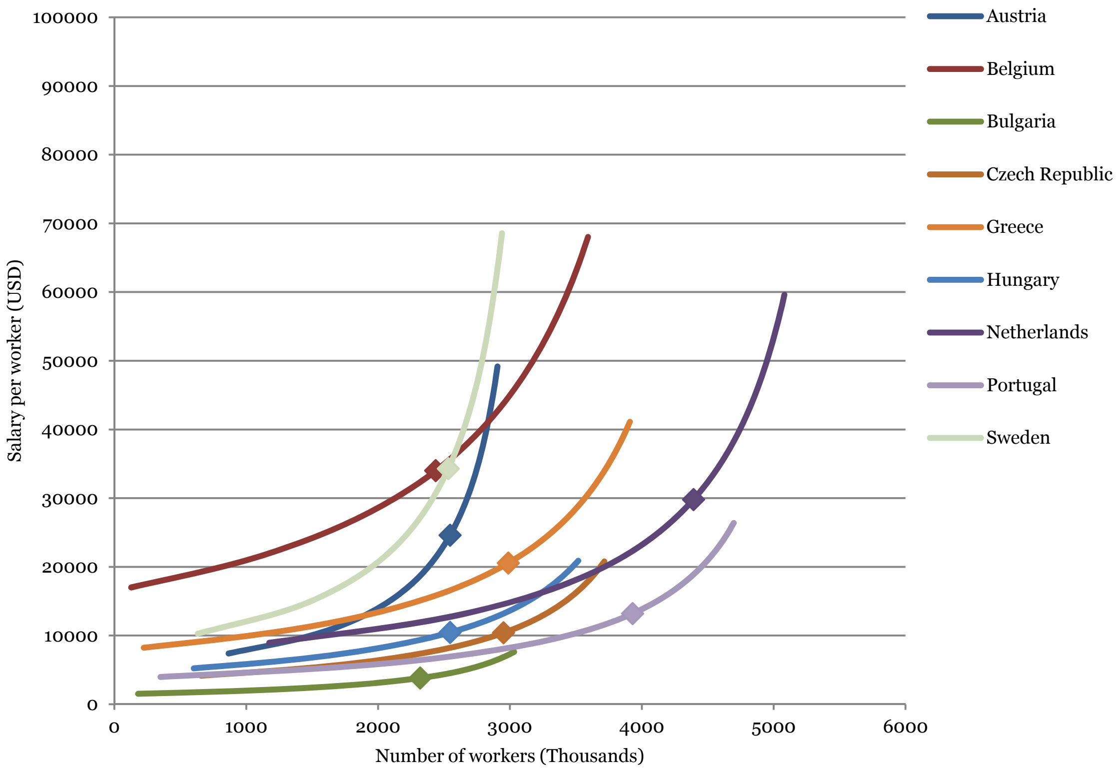
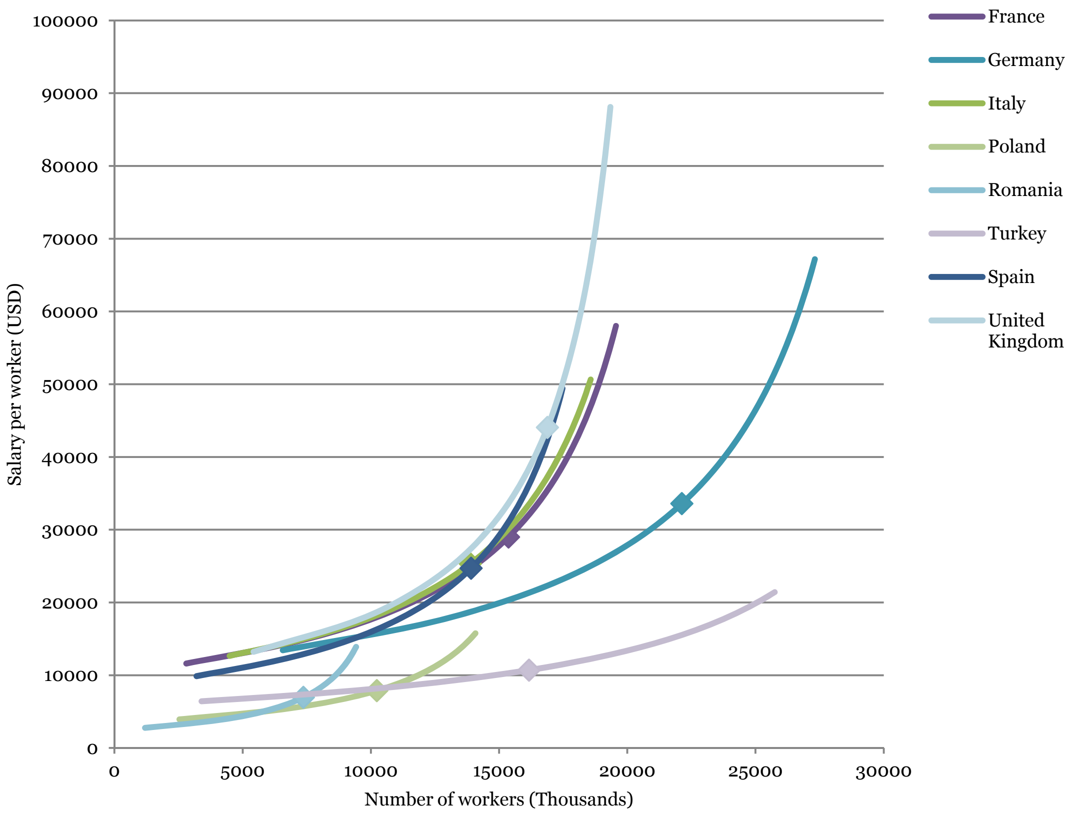


Figure 11 Labour supply curves for large European member and candidate states



The disparity between wage levels among the EU15 countries and the new and candidate states is even more distinct among the larger European countries. The labour supply curves for the larger countries as shown in Figure 11 are clearly clustered into two groups: the upper group of EU15 member states with higher wages and steeper labour supply curves and the lower group of new and candidate member states with lower wage levels and shallower supply curves. This analysis shows a clear difference in the average wage levels of EU15 and newer member states as well as highlighting that the market for unskilled labour in the new and candidate states shows some spare capacity whilst that of the older member states is more closely approaching fully employment. As such, increase in the demand for unskilled labour in the new member states will have less impact on wage rates than the same increase in the EU15 countries. Interestingly, Turkey has a slightly higher average wage than Poland and Romania in 2007 but is less labour-constrained as reflected by the shallower supply curve.

4.1.3 Scenarios & Model Specification

The specification of a labour supply curve for each EU member and candidate state offers an alternative way of modelling the labour supply to the two extremes of spare capacity and full employment. This middle-way is incorporated into the MAGNET CGE model to improve the degree to which the model can capture the heterogeneous nature of European labour markets. This extension, and its impact on the results of a standard CAP reform scenario, is introduced in this section.

4.1.3.1 Scenario specification

The new labour supply curves are introduced into the MAGNET model and tested with a set of three scenarios to show the effect of changes in the representation of the labour market on the impact of a change in the CAP budget. Specifically the scenarios are defined as[10]:

Scenario 1 'Spare Capacity': a 50% reduction in first pillar support to all EU member states under the assumption of spare capacity in the supply of unskilled labour. Skilled labour in all regions as well as unskilled labour in the Rest of the World region is assumed to be fully employed.

Scenario 2 'Labour Supply Curve': a 50% reduction in first pillar support to all EU member states under the assumption of an upward-sloping labour supply curve for unskilled labour. Skilled labour in all regions as well as unskilled labour in the Rest of the World region is assumed to be fully employed.

Scenario 3 'Full Employment: a 50% reduction in first pillar support to all EU member states under the assumption of fully employed unskilled labour. Skilled labour in all regions as well as unskilled labour in the Rest of the World region is also assumed to be fully employed.

The scenarios therefore differ only in the specification of the unskilled labour market in the EU with scenario 3. It should be noted that full employment refers to the total use of the factor across the whole economy, rather than sector specific use. As such, the quantity demanded by sectors may change but any extra labour use must be attracted from other sectors through higher wages. Conversely, any reduction in demand by one sector will increase the availability of labour, lowering wages to ensure that other sectors increase their demand and that all workers are fully employed.

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[10] The model 'closure rules' that determine the specification of the unskilled labour market in each scenario are:

Scenario 1: endogenous unskilled labour supply (qo) and exogenous unskilled wage (pfactreal)

Scenario 2: endogenous unskilled labour supply and wages with exogenous asymptote (p_labasymp)

Scenario 3: endogenous unskilled wage with exogenous unskilled labour supply

4.1.3.2 Model specification

All three scenarios are implemented in a comparative static version of the MAGNET model starting from a base year of 2007. The MAGNET model is a CGE model calibrated to Version 8 of the GTAP database which includes 129 countries/regions, 57 commodities and 5 factors of production: land, unskilled labour, skilled labour, capital and natural resources. The MAGNET system has at its core the GTAP model which, through a set of tailor-made modules, can be extended with a number of features. Current MAGNET modules include endogenous land supply, an extended production structure, bilateral tariff rate quotas, biofuels, Common Agricultural Policy and alternative specifications for consumption and investment. The development of the labour supply curve as part of the Factor Markets projects forms a further module.

The modular nature of the MAGNET model allows the form of the model to be specified for the research question at hand. The illustrative nature of the scenarios included in this analysis suggests a relatively simple model set-up to highlight the effect of changing the labour market specification. The MAGNET model used for this analysis is therefore the GTAP core plus endogenous land supply in all regions, Common Agricultural Policy in EU member states and the labour supply curve module (in Scenario 2). The endogenous land supply curve is used because the policy scenario pertains to the agricultural sector and specifying a land supply curve allows the amount of land and its price to vary, rather than keeping the total amount of land used fixed across the agricultural sector[11].

4.1.3.3 Model aggregation

The latest version of the GTAP database covers 129 regions and 57 commodities. As with the model specification, the choice of aggregation over which regions and commodities to include separately also depends on the research question. The focus here on the results of CAP reform under alternative labour market functioning in the EU necessitates a geographical focus on Europe and a commodity focus on agricultural commodities. A full list of the regions used in the model is shown in Table 5 with a list of the commodities included in the model given in Table 6.

Table 5. Country aggregation

Country/Region	Short name	Country/Region	Short name	Country/Region	Short name
Austria	aut	Germany	deu	Poland	pol
Belgium	bel	Greece	grc	Portugal	prt
Bulgaria	bgr	Hungary	hun	Romania	rou
Croatia	hrv	Ireland	irl	Slovakia	svk
Cyprus	cyp	Italy	ita	Slovenia	svn
Czech Republic	cze	Latvia	lva	Spain	esp
Denmark	dnk	Lithuania	ltu	Sweden	swe
Estonia	est	Luxembourg	lux	Turkey	tur
Finland	fin	Malta	mlt	United Kingdom	gbr
France	fra	Netherlands	nld	Rest of the World	row

[11] Agricultural sectors are the only users of land in the GTAP database.

Table 6. Commodity aggregation

Commodity	Short name	Composition
Cereals	cer	Wheat, maize, rice, other grains
Vegetables & fruit	v_f	Vegetables, fruit, nuts
Animal products	anpr	Bovine cattle, sheep and goats, horses raw milk, wool, silk-worm cocoons, other animal products
Other crops	ocp	Oil seeds, sugar cane, sugar beet, plant-based fibres, other crops
Manufacturing	mnfc	All manufacturing including food processing, fishing and forestry
Services	serv	All services including utilities and transport

4.1.4 The effect of changes in the labour market specification on the results of a CAP reform scenario

The supply of endowments to an economy and the ability to take-on or shed workers in response to economic shocks and policy changes are important determinants of macroeconomic performance. Factors comprise a significant share of production costs to firms and form the major source of income to households. As such, the supply of factors provides a link between the production and consumption sides of an economy and, to the extent that GDP is measured by value added, the primary determinant of national income. Given the key role of factors in the economy, it is expected that changing the labour market specification will change the outcome of policy simulations.

4.1.5 Scenario results

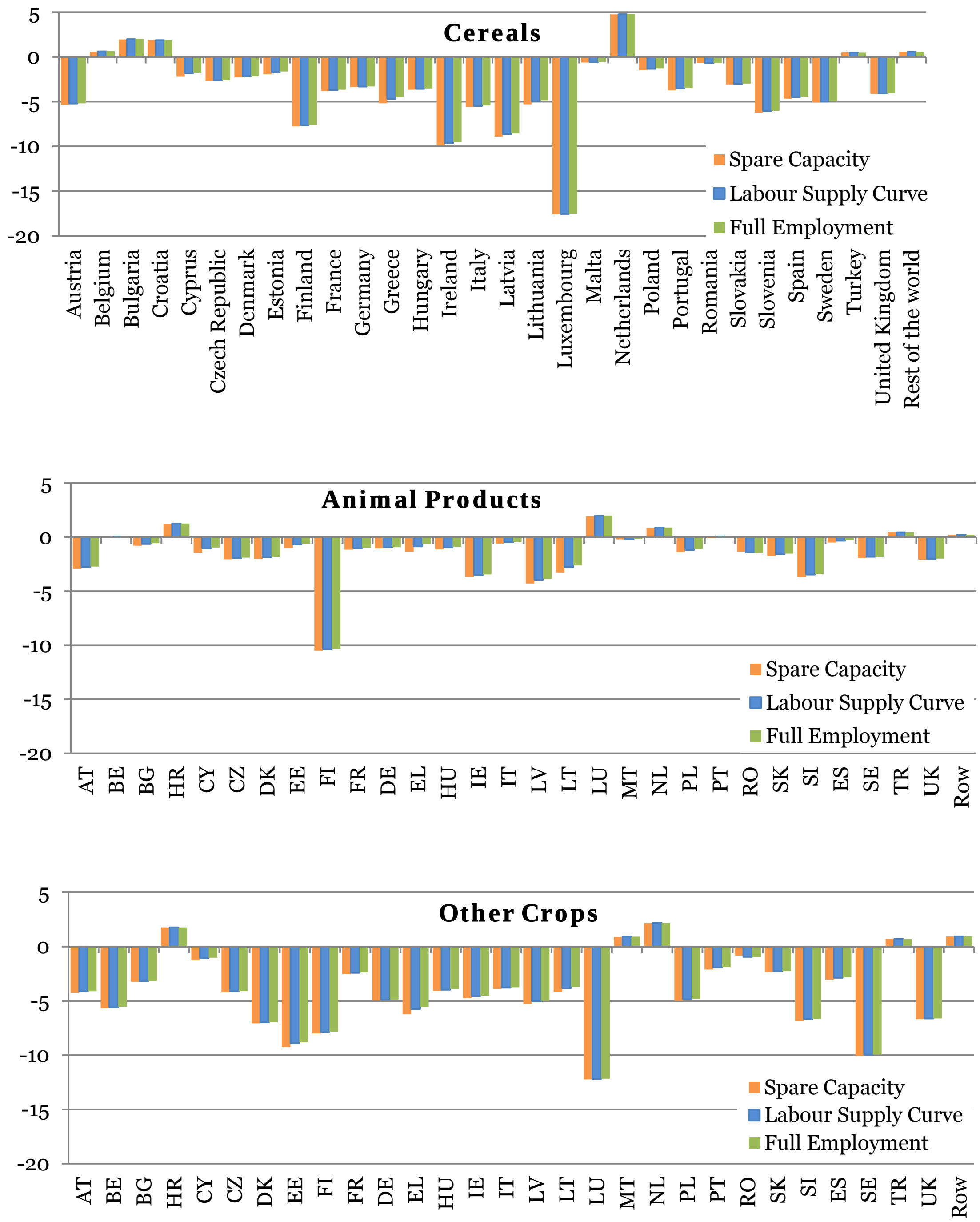
The results of three simulations in which the same change in CAP policy is analysed with different labour market assumptions are presented in this section. A priori expectations suggest that a 50% reduction in first pillar support in member states will increase production costs resulting in a contraction of the agricultural sector. This expectation is largely borne out in all countries and agricultural sectors across the EU as shown in Figure 12. The large contractions are seen in the Luxembourg cereals and crops sectors (17% and 12% respectively), the Irish vegetables and fruits sector (12%) and the Finnish animal sector (10%). The average contraction across the EU member states is greatest in the crops sector (4.5%) and lowest in the animal products sector (1.6%); with cereals and vegetables and fruits falling between these two extremes.

Although the general pattern is one of contraction in the agricultural sectors, the reduction in first pillar support increases production in some sectors in some countries. The agricultural sector in Croatia, Turkey and the Rest of the World region expands as rising costs in the EU leads to relatively cheaper prices in these regions, boosting demand. A similar effect drives the expansion in agriculture in some of the smaller countries such as the Netherlands and Malta. The expanding countries, although member states, are recipients of lower levels of initial CAP support. Cutting the support to these countries therefore leads to smaller increases in production costs, making their agricultural products relatively cheaper. The 4.8% expansion of the cereals sector in the Netherlands for example, is due to export-led growth brought about by relatively cheaper prices compared with other member states.

The change in the output of the agricultural sectors from the CAP reform scenario is also shown for each of the labour market specifications in Figure 12. Whilst the change in labour market functioning doesn't alter the overall conclusions of the results, it does lead to different results. An assumption of full employment in unskilled labour leads to smaller contractions in all agricultural sectors in all countries than the assumption of spare capacity. This is due to the assumption of mobile unskilled labour across sectors. Under full employment, the wage rate adjusts to ensure that all labour that is released from the agricultural sector is employed by other sectors. The assumption of mobile labour however means that this reduction in wages is equalised across all sectors and also reduces the wage bill in agriculture. This reduction in wage costs means that production costs and therefore output contracts by less than in the case of spare capacity where the released workers return to the inactive pool having no effect on the equilibrium wage rate.

The introduction of a labour supply curve produces results that fall strictly between those of the spare capacity and full employment scenarios as expected. The proximity of the result under the assumption of an upwards-sloping labour supply curve depends upon the shape of the curve: countries with flatter curves and therefore more spare capacity in unskilled labour have changes in the agricultural sector closer to the spare capacity results.

Figure 12. Percentage change in the output of agricultural sectors



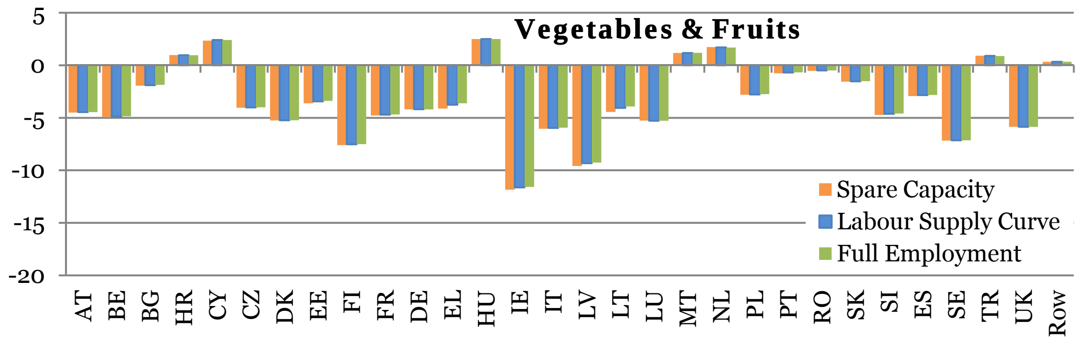
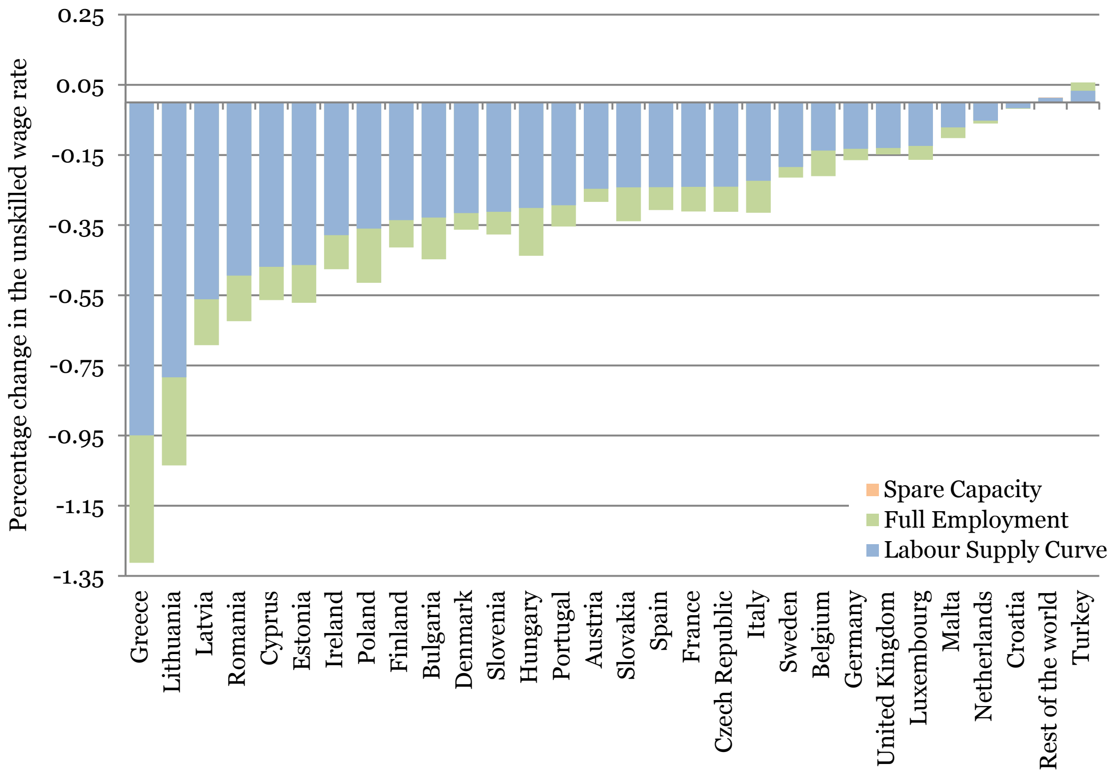


Figure 13. Percentage change in unskilled wage rate



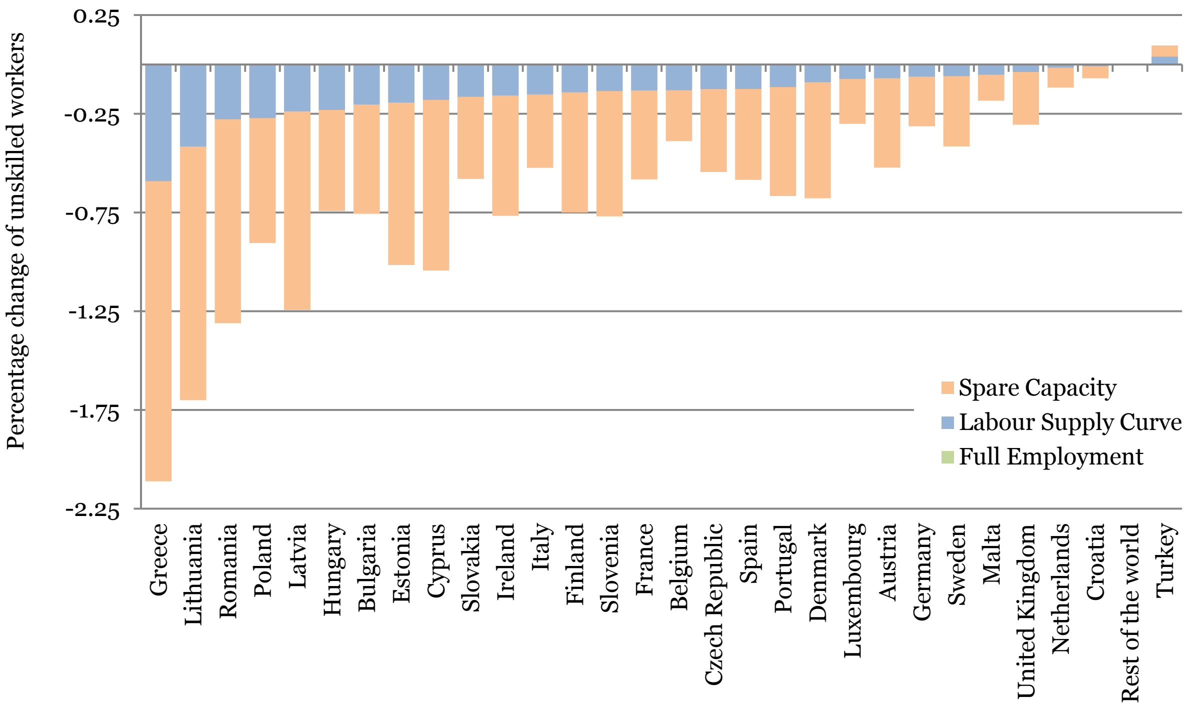
Note: Results are ranked by size of labour supply curve effect and overlaid rather than stacked.

Conversely, countries with steeper labour supply curves experience changes in the agricultural sectors that are closer to the full employment results. As such the introduction of a labour supply curve for unskilled labour slightly dampens the effects of the cut in the CAP budget compared with the standard model specification of fully employed unskilled labour.

Whilst the largest difference in the expansion of the agricultural sectors under the various scenarios is still relatively small (0.7% for the cereal sector in Greece), the impact of changing the labour market specification on the supply of labour and wages is more marked. The percentage change in the wages of unskilled labour resulting from a 50% cut in first pillar support to member states is shown in Figure 13. The reduction in support to agriculture reduces the demand for unskilled labour and lowers wages in the member states as more unskilled labour is available for use in other sectors. Wages increase by more under the assumption of full employment to entice other sectors to 'mop up' the excess labour. As expected, wage increases under the labour supply curve assumption also increase but by less than the full employment scenario to reflect the fact that the economy can also adjust the total number of people in employment. Wages do not alter under the assumption of spare capacity as all adjustment is made through the number of people employed. Countries near full employment (such as the Netherlands) show changes in wages that are similar under the full employment and labour supply curve assumptions.

The changes in the quantity of unskilled labour employed tell a similar story as shown in Figure 14. The quantity of labour adjusts most under the spare capacity assumption where all adjustment takes place through the employment level. Some reduction in employment also takes place under the labour supply curve assumption as expected. There is no change in employment under the full employment assumption where all adjustment takes place through the wage rate.

Figure 14. Percentage change in quantity of unskilled labour

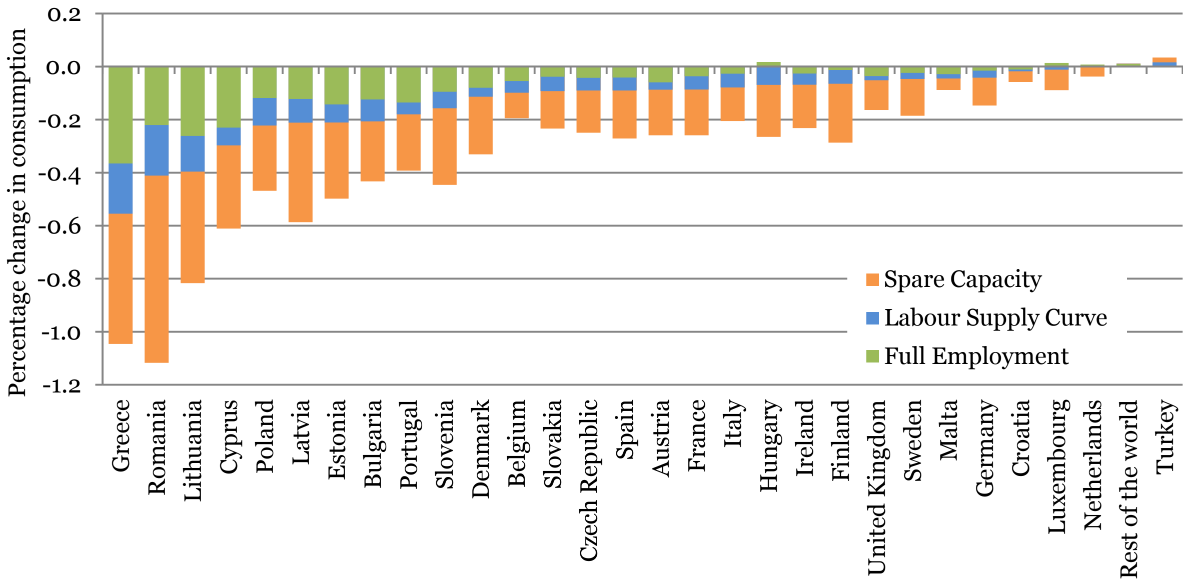


Note: Results are ranked by size of labour supply curve effect and overlaid rather than stacked.

These relatively large changes in employment and wages in some countries have important implications for welfare as shown in Figure 15. Consumption by households, considered here as a proxy for welfare, is reduced in all the contracting member states. The reduction in welfare is more pronounced under the assumption of spare capacity as some workers will have been made unemployed as a result of the CAP reform.

The specification of the labour market therefore has a small effect on the impact in the agricultural sector but a relatively large impact on the welfare effect of a cut in first pillar support. Improving the modelling of factor markets in the member and candidate states is therefore important not only for capturing the heterogeneity of labour markets but also the welfare effects of policy reform.

Figure 15. Percentage change in consumption by households (welfare)

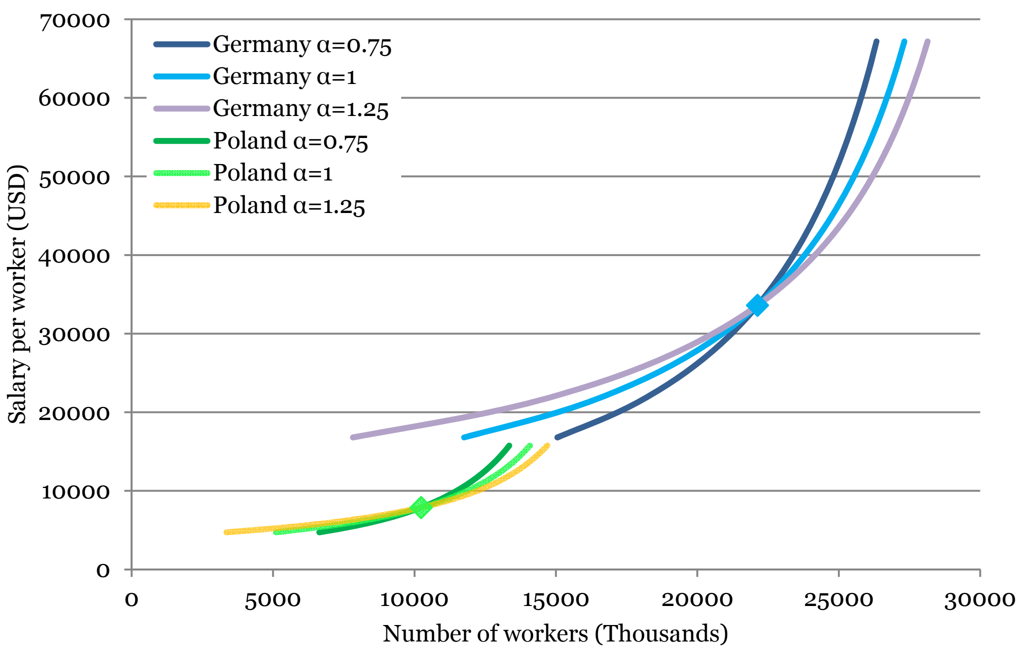


Note: Results are ranked by size of labour supply curve effect and overlaid rather than stacked.

4.1.6 Sensitivity analysis

The above analysis is conducted with the power of the labour supply function (α) set equal to one. This parameter is the only component of the labour supply function that isn't specified from real world data. As such, it is important to consider how sensitive the results of the scenarios are to the choice of this parameter.

Figure 16. The impact of changing the power of the labour supply function

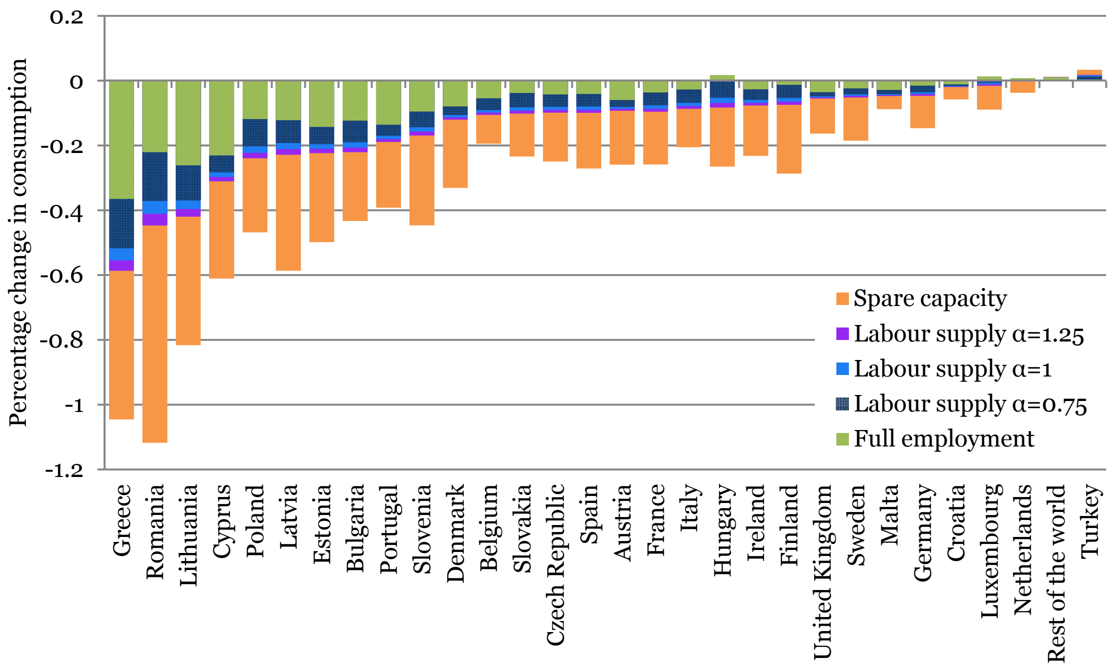


The power of the labour supply function governs the impact of a change in wages on employment. Changes in the power therefore change the slope of the curve with lower powers reducing the sensitivity of employment to changes in the wage rate as reflected by a steeper curve. Conversely, higher powers increase the employment response to a change in wages as shown by more shallow curves. The impact of changing the power of the labour supply functions is illustrated for two countries, Germany and Poland, in Figure 16. The two countries are shown as they reflect initial situations of relative full employment (Germany) and relative spare capacity (Poland) in the unskilled labour market. In each case, reducing the power of the labour supply function by 25% or increasing it by 25% pivots the curve about the initial equilibrium point.

The results of a sensitivity analysis of the power of the labour supply function are presented in Figure 17. The labour supply scenario is rerun with values of the power of -25% and +25% the initial value for all regions. The pattern of the welfare results are consistent with that of the other results of the model: changing the power of the labour supply function and therefore the shape of the labour supply curve, produces results that are closer to the spare capacity results for increases in the power and close to the full employment results for decreases in the power.

Changes in the power of the function of plus and minus 25% have a fairly symmetric impact on the results; the increase in the power leads to welfare results that are on average 13.7% below the standard labour supply results and a decrease in the power leads to welfare results that are 15.1% higher than the standard results. Therefore, although changes in the power of the function lead to results that are fully consistent in that they lie within the extremes of the labour market specification, the results are still relatively sensitive to changes in this parameter. To this end, any analysis using the new labour supply curve specification should either use an econometric estimation of this parameter or report results with bounds based on a range of values of the power of the function.

Figure 17. Impact of sensitivity analysis on welfare results



Note: Results are ranked by size of labour supply curve effect (α=1) and overlaid rather than stacked.

4.1.7 Conclusions and future work

This paper introduces an extension to the MAGNET CGE model to better capture the heterogeneous nature of labour markets across the member and candidate states. Specifically, the model is extended by introducing a labour supply curve for each country to allow for a more sophisticated relationship between labour supply and the real wage beyond the two extremes of spare capacity and full employment that are normally considered in CGE models.

The paper introduces the theoretical foundations of the labour supply curve and then empirically derives unskilled labour supply curves for all member states and Croatia and Turkey. The analysis of these supply curves shows that the new member and candidate states have systematically lower average wages than the EU15 countries and are often less labour constrained. Integrating the labour supply curves into the MAGNET CGE model and using the extended model to evaluate the impact of CAP reform under different labour market assumptions shows that the addition of labour supply curves is a valuable one. The new specification produces results that fall between the two extremes of spare capacity and full employment, capture the relative flexibility of the labour markets across Europe and produce more nuanced welfare results.

There is considerable scope for extending the analysis presented here and as such, this paper forms the first results of this new area of work. Future plans include a similar analysis on the skilled labour market across Europe, the integration of this approach with the segmented agricultural labour markets that already exist in the model and extending the approach across time in a dynamic framework. Econometric estimation of the parameter governing the power of the labour supply function would also be a valuable area for further research.

5. Land

5.1 Renewable Energy Directives versus Reducing Emissions from Deforestation and Degradation: Biofuel policy versus forest conservation

5.1.1 Background

A rapid growth in worldwide biofuel production has been observed since 2001, driven by Renewable Energy Directives (RED) and high crude oil prices, as well as a growing interest in reducing Greenhouse Gas (GHG) emissions. There are increasing concerns, however, that the demand for land for biofuel production may be leading to increased deforestation (Banse et al. 2008, Banse et al. 2011, Hertel et al. 2010), resulting in biodiversity losses and higher GHG emissions. Deforestation and forest degradation, together with peatland emissions, have been shown to account for between 15% (Werf et al. 2009) and 20-25% of greenhouse gas emissions, a total that is higher than the entire contribution of the transportation sector (Myers, 2007).

The United Nations REDD programme seeks to Reduce Emissions from Deforestation and forest Degradation by protecting and managing forests and woodlands (UN-REDD, 2011). Any effort to limit deforestation is also likely to limit the land available for increasing agricultural production, including biofuel production stemming from RED policies. The restriction of available land by REDD policies is therefore likely to change the pattern of comparative advantage in agricultural production between countries, leading to changes in agricultural prices, trade and food security. However, these effects, together with the land use impacts of REDD policies across the world, are not well understood and, to date, there have been no studies of the interaction of RED and REDD and little discussion in the policy arena.

This paper assesses the complex interplay between global renewable energy directives (RED) and the REDD programme to limit deforestation and forest degradation. We examine the interaction of the two policies using a scenario approach with a global CGE model and address a key methodological challenge of how to model the supply of land in the face of restrictions over its availability, as arises under the REDD policy. The consequences of a global biofuel directive on worldwide land use, agricultural production, international trade flows, food prices and food security, are evaluated with and without a strict global REDD policy. The advantage of such a modelling approach is that the feedback effects between agricultural, biofuel, energy and other markets are captured (Rajagopal and Zilberman, 2007). In addition, the transmission of the impact of RED and REDD policies to other regions of the world through endogenous impacts on agricultural prices and land returns are captured. The economy-wide coverage of the CGE model also enables the impact on food security and the balance of trade to be evaluated.

5.1.2 Modelling land use, RED and REDD

Capturing the interaction of RED and REDD policies requires a global multi-sector approach that accounts for both the changes in restrictions on land availability arising from the REDD agreements and changes in energy and agricultural markets arising from biofuel directives.

5.1.2.1 Modelling framework

The policy scenarios are implemented in the MAGNET model, a multi-regional, recursive-dynamic, applied general equilibrium model based on neo-classical microeconomic theory (Nowicki et al. 2009, van Meijl et al. 2006). MAGNET is based on the standard GTAP model (Hertel, 1997) and has at its core, an input–output model that links industries in a value added chain from primary goods, over continuously higher stages of intermediate processing, to the final assembling of goods and services for consumption. Goods at any stage of production can be traded between regions. The MAGNET model goes beyond the standard GTAP model with an improved representation of five policy-relevant dimensions: first, the agricultural sector by including imperfectly substitutable types of land, a land use allocation structure, land supply function and substitution between various animal feed components; second, agricultural policy by including production quotas and different land-related payments; third, biofuel policy by including capital-energy substitution, substitution between fossil and biofuels; fourth, shifting consumption patterns as incomes rise through the addition of a dynamic CDE expenditure function to allow for changes in income elasticities as purchasing power parity corrected real GDP per capita changes; finally, the observed differential in agricultural and non-agricultural wages and returns by introducing imperfect mobility between agricultural and non-agricultural labour and capital markets.

The model is calibrated to version 6 of the GTAP database (Dimaranan, 2006), which contains detailed bilateral trade, transport and protection data characterizing economic linkages among regions and detailed country input-output databases that account for domestic inter-sectoral linkages. All monetary values of the data are in million U.S. Dollars and the base year for version 6 is 2001 which is updated to 2010 using macroeconomic and yield data. The 88 regions in the GTAP database are aggregated to 45 regions for simulation purposes. The regional results are then aggregated to 12 larger regions for presentation purposes which are chosen as important from an agricultural production and demand point of view. The definition of the twelve presentation regions is given in Table 7.

Similarly the 57 sectors identified in the database are aggregated to 26 sectors that produce 28 products. The sectoral aggregation includes: land-using agricultural sectors such as rice, grains, wheat, oilseed, sugar, horticulture, other crops, cattle, pork and poultry, and milk; the petrol sector that demands fossil (crude oil, gas and coal) and bioenergy inputs (ethanol and biodiesel); and by-products of biofuels production.

5.1.2.2 Modelling the response of agricultural land to REDD

Most CGE models assume that the total amount of land available for agriculture is fixed and unaffected by changes in the land price and therefore, the total amount used is always equal to the amount of land available. Consequently, no land can move outside of agricultural production. However, converting land from forestry to agricultural use or vice versa, may occur as a consequence of policy changes or changes in demand for agricultural products.

Table 7. Membership of aggregated regions

Region	Members
Europe	Belgium, Luxembourg, Denmark, Germany, Greece, Spain, France, Ireland, Italy, The Netherlands, Austria, Portugal, Finland, Sweden, United Kingdom, Cyprus, Malta, Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, Slovenia, Slovakia, Bulgaria, Romania, Switzerland, Albania, Croatia, Rest of EFTA, Rest of Europe
Central & South America	Mexico, Central America, Brazil, Colombia, Peru, Venezuela, Argentina, Chile, Uruguay, Rest of FTAA, Rest of the Caribbean, Rest of the Andean Pact, Rest of North America and Rest of South America
USA	United States of America
Canada	Canada
Southern Africa	South Africa, Botswana, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe, Rest of Southern African Customs Union and Development Community
Rest of Africa	Morocco, Tunisia, Uganda, Madagascar, Rest of North Africa, Rest of Sub-Saharan Africa
Former Soviet Union	Post-Soviet states, excluding the Baltic states
China	China, Hong Kong, Taiwan and Rest of East Asia
Southeast Asia	Malaysia, Philippines, Singapore, Thailand, Vietnam, Rest of Southeast Asia
Indonesia	Indonesia
Oceania	Australia, New Zealand, Rest of Oceania
Rest of Asia	India, Bangladesh, Sri Lanka, Japan, Korea, Turkey, Rest of Middle East, Rest of South Asia

In specifying the land supply for each country, we started with simple functions of the form

$$P = F(L, \Gamma) \tag{1}$$

where

P is the real rental price of agricultural land;

L is the supply of land to agricultural activities;

Γ is an upper bound on the supply of agricultural land, that is the total potential land that could be available for agriculture; and

F is a function defined for $L < \Gamma$ with the properties that

$$\frac{\partial F}{\partial L} > 0 \text{ and } P \to \infty \text{ as } L \to \Gamma\,. \tag{2}$$

An example of a function with these properties is[12]

$$P = \frac{A}{\exp\{B*(\Gamma - L)\} - 1} \tag{3}$$

where A and B are parameters with the same sign (either both positive or both negative).

[12] Another example is P=(A/(□□-L))^B, again with A and B as parameters. This form was used in LEITAP, a forerunner of the MAGNET model (Meijl et al. 2006; Eickhout et al. 2009; and Nowicki et al. 2009). However, the choice between these forms is not important. The fundamental change made in this paper is to treat A and B as variables, thereby facilitating simulations of the effects of changes in total available land.

It became apparent, however, that a simple function such as (3) with A and B specified as parameters is unsuitable for simulating the effects of REDD which involves large reductions for some countries in potential land availability (Γ). Large changes in Γ with A and B treated as parameters can introduce unrealistic shifts in the supply curve in the neighbourhood of actual land use (L). This is illustrated in Figure 18 for the case of Canada in which REDD requires an 82 per cent reduction in potential agricultural land from 7.9 times land in use to 1.422 times land in use. In drawing Figure 18, we assumed that units are chosen so that the initial quantity of land in use is one, implying that the initial value for Γ (denoted as Γ_I) is 7.9. Similarly we chose monetary units so that the initial real rental rate on land is one. Then we set A and B to satisfy the equations

$$1 = \frac{A}{\exp\left\{B * \left(\Gamma_I - 1\right)\right\} - 1} \tag{4}$$

$$0.95 = \frac{A}{\exp\left\{B * \left(\Gamma_I - \left[1 - 0.05 * E\right]\right)\right\} - 1} \tag{5}$$

where E is the elasticity of land supply in the vicinity of the initial equilibrium.[13] Equations (4) and (5) imply that a 5 per cent reduction in price (from 1 to 0.95) corresponds to a percentage reduction in land supply of 5 times E per cent (from 1 to 1-0.05*E).[14]

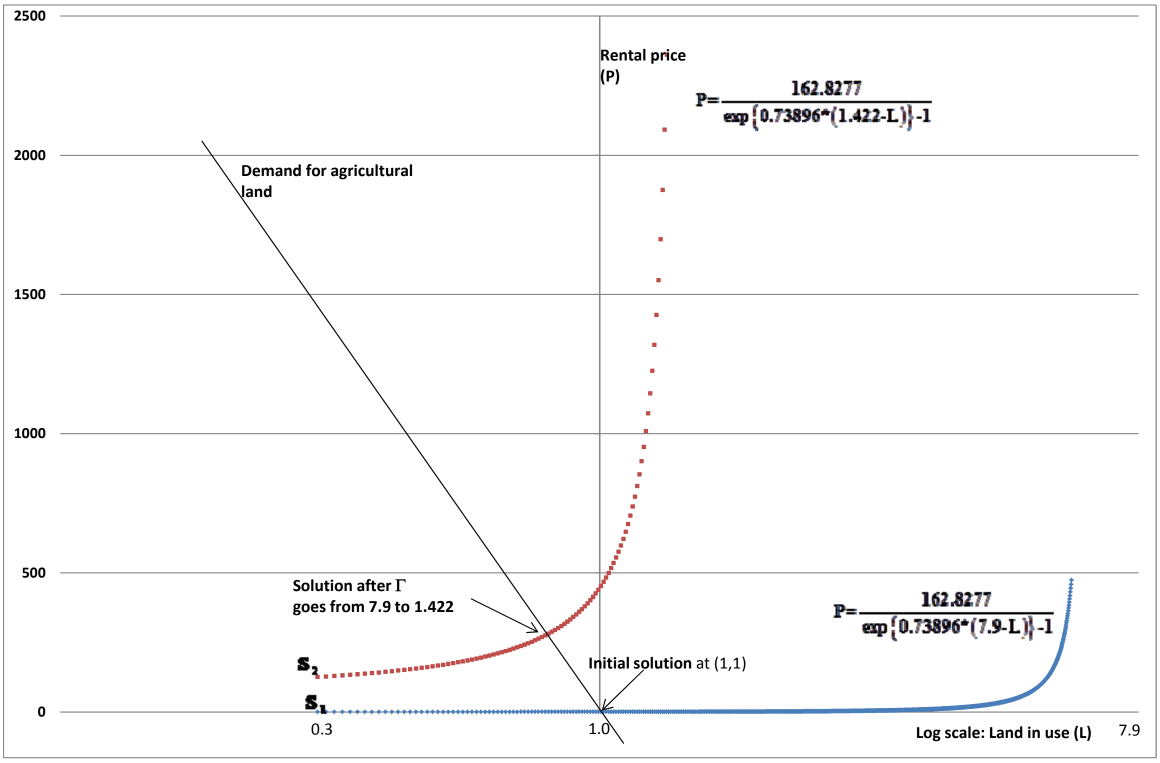
For Canada, E is 1.38, giving A = 162.8277 and B = 0.73896. With A and B treated as parameters, the movement in Γ from 7.9 to 1.422 shifts the Canadian land-supply curve in Figure 18 from S1 to S2. Under any plausible specification of demand for agricultural land, this supply shift causes an enormous and unrealistic price increase (from 1 to about 280 in Figure 18) and a corresponding large quantity decrease.

Our analysis of Figure 18 suggested that A and B should be treated as variables that respond to changes in Γ. In particular, A and B should be allowed to change so that a reduction in Γ does not influence very much the position of the land-supply function for values of L well below the initial value. In addition, we decided to control the movements in A and B so that a reduction in Γ causes only a small leftward shift in the supply curve in the neighbourhood of the initial solution if the percentage of available agricultural land in use is low. Thus an 82 per cent reduction in Γ when L/Γ is equal to 1/7.9 should have little effect on the relevant part of the supply curve. By contrast, a small reduction in Γ should have a large effect on the relevant part of the supply curve if a high fraction of potential agricultural land is in use.

[13] The elasticity values used in (5) were provided by Cixous (2006) for EU countries or derived from biophysical data from the IMAGE modelling framework (see Alcamo et al. 1998).

[14] Thus E is an arc elasticity (rather than a point elasticity) calculated from the effects of a 5 per cent price reduction. The choice of 5 per cent is a matter of convenience. Other small percentage values could have been used with little effect on the calibrated values for A and B.

Figure 18. Demand and supply for land: Canada with A and B in (3) treated as parameters



Because REDD operates mainly by removing current forest/wilderness land from potential use in a country's agricultural sector, not actual use, it could be argued that there should be no effect on land-supply curves in the neighbourhood of the current rental/land-supply equilibrium. Against this, consider a situation in which owners of potential agricultural land make supply decisions stochastically each period. In a country in which there are n blocks of potential agricultural land, the number of blocks that will be supplied when P= 1 is given by

$$L = \sum_{i=1}^{n} Pr_i\left(P = 1\right) \tag{6}$$

where $Pr_i(P=1)$ is the probability that the owner of block i will supply this block to agriculture when the rental price is 1.

The imposition of REDD can be thought of as changing some of these probabilities from positive values to zero, thus reducing L even if no land currently used in agriculture is directly affected by REDD. For a land-abundant country such as Canada, we would expect REDD to withdraw from potential supply mainly blocks with low probabilities of supply at the current rental rate. Thus, we would expect REDD to cause only a small leftward movement of the supply curve in the neighbourhood of the initial equilibrium. For land-scarce countries such as the Netherlands we would expect REDD to withdraw from potential supply blocks with relatively high probabilities of supply at the current rental rate. Thus for these countries we would expect REDD to cause a significant leftward movement of the supply curve in the neighbourhood of the initial equilibrium.

To achieve these desired properties for land-supply curves, we computed initial values for A and B according to (4) and (5). Then we computed $P_I(0.5)$, the rental price on the initial supply curve with land supply at half its initial value, according to:

$$P_I\left(0.5\right) = \frac{A_I}{\exp\left\{B_I * \left(\Gamma_I - 0.5\right)\right\} - 1} \tag{7}$$

where A_I, B_I and Γ_I are the initial values of A, B and Γ. Finally, we introduced two new equations to determine movements in A and B away from their initial values in response to changes in Γ:

$$P_I(0.5) = \frac{A}{\exp\left\{B*\left(\Gamma - 0.5\right)\right\} - 1} \tag{8}$$

and

$$1 = \frac{A}{\exp\left\{B*\left(\Gamma - \left(\frac{\Gamma}{\Gamma_I}\right)^{\frac{1}{(\Gamma_I)^{1.25}}}\right)\right\} - 1} \tag{9}$$

Equation (8) anchors the supply curve: irrespective of the value of Γ the land-supply curve passes through (L,P) = (0.5, P_I(0.5)). This ensures that reductions in Γ do not influence very much the position of the land-supply function for values of L well below its initial value. Via equation (9) we control the extent to which the supply curve shifts to the left at the initial rental price. At P = 1, equation (9) forces L to the adopt the value

$$L(P=1) \ = \ \left(\Gamma/\Gamma_I\right)^{\left(1/\Gamma_I^{1.25}\right)} \tag{10}$$

Under (10), for a given value of Γ_I, the smaller is Γ/Γ_I the larger is the leftward shift in the land-supply curve [that is the smaller is L(P=1)]. And for any given value of Γ/Γ_I, the leftward shift is smaller for larger values of Γ_I. This second property can be accentuated or damped through different choices for the 1.25 exponent. We arrived at 1.25 after initially judging that leftward supply shifts were too great without the exponent (an implicit value of 1).

In the Canadian case in which Γ is reduced from an initial value of 7.9 to 1.422, the leftward movement in the supply curve at P = 1 is 0.12, that is the quantity supplied at the initial price falls by 12 per cent. This is illustrated in Figure 19. For countries with less abundant land in comparison with their land use, $1/(\Gamma_I^{1.25})$ is larger. This means that these countries experience a larger leftward shift in their supply curve (percentage reduction in land use at the initial rental rate) for any given percentage reduction in the asymptote (Γ). This is illustrated in Figure 20 where an 82 per cent reduction in the asymptote from 6 to 1.08 causes a leftward shift of 17 per cent (compared with 12 per cent in Figure 19).[15]

[15] In drawing Figures 3 and 4 we continue to assume that E = 1.38.

Figure 21 is a further illustration of the effect on the supply curve of a reduction in Γ. Here Γ is reduced by only 40 per cent, from 2 to 1.2. Reflecting the relative initial scarcity of land, the reduction in Γ causes a leftward shift in the supply curve of about 19 per cent, greater than in the previous two cases in which the reduction in Γ was 82 per cent.

Figure 19. Land supply function for Canada as Γ declines by 82% from 7.9 to 1.422

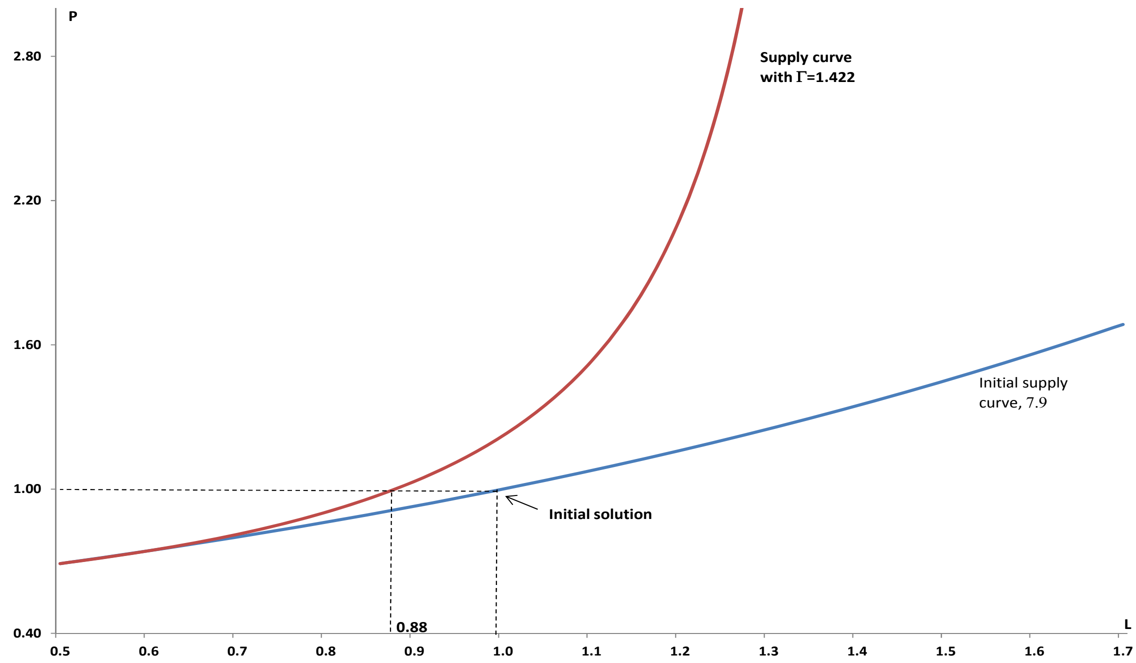


Figure 20. Land supply function as Γ declines by 82% from 6 to 1.08

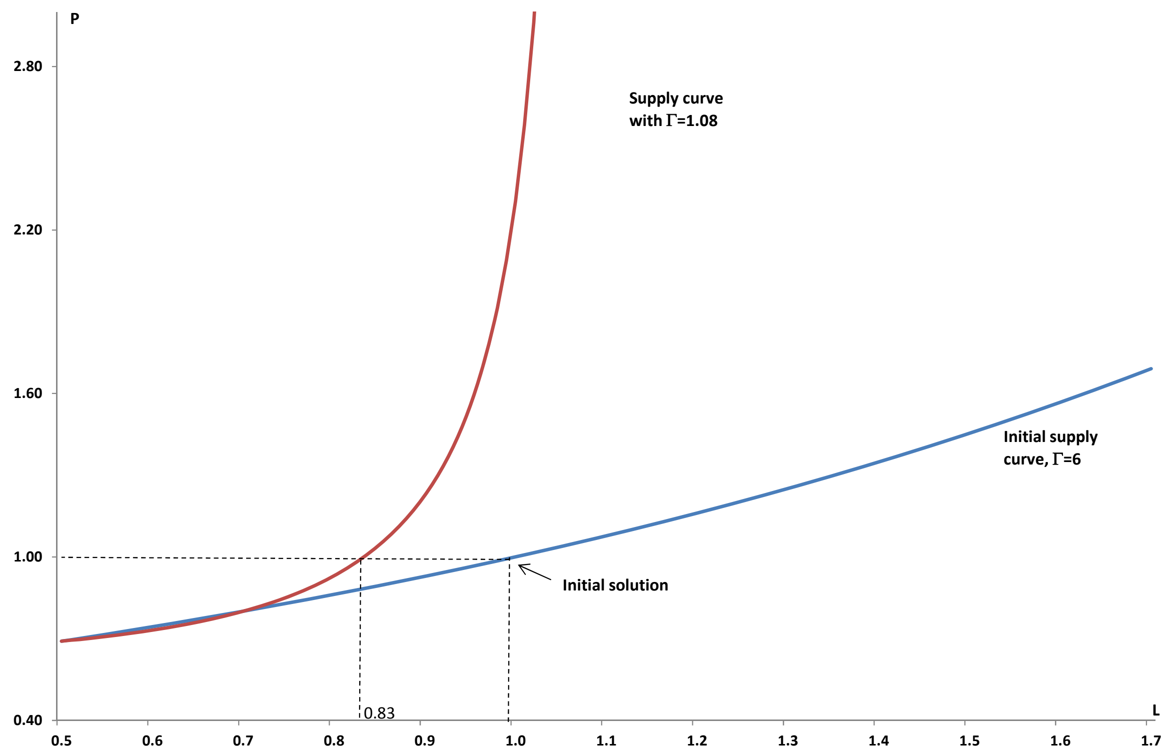
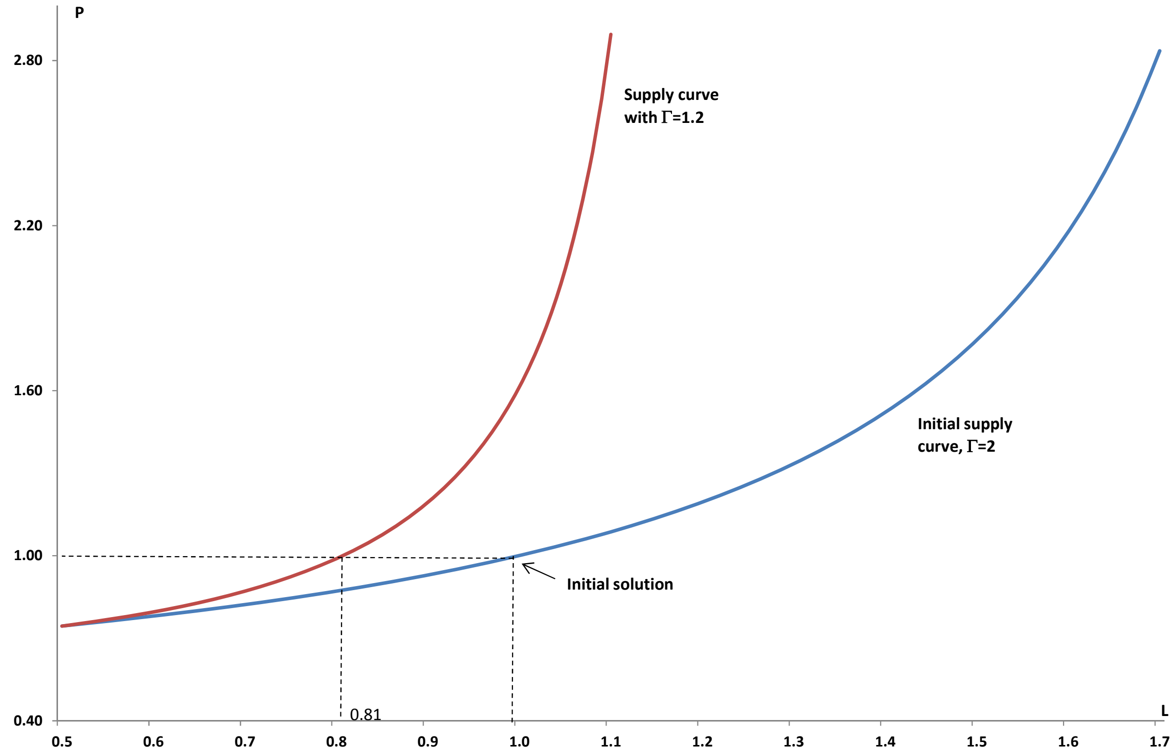


Figure 21. Land supply function as Γ declines by 40% from 2 to 1.2



We implemented specification (3), (8) and (9) in the GEMPACK[16] representation of MAGNET via linear change forms with P, L A, B and Γ treated as variables.

Including biofuels in energy markets

Two new energy sectors, ethanol and biodiesel, are introduced to improve the representation of biofuels in the model. The ethanol sector produces ethanol and a by-product of Dried Distillers Grains with Solubles (DDGS). Similarly, the biodiesel sector produces the primary product and a by-product of oilseed meals (BDBP). Both biofuels are introduced as direct competitors to crude oil in the model through their inclusion in the production structure of the petrol sector that produces motor-fuel. A subsidy on biofuels is introduced to ensure that the ratio of biofuel to crude-oil inputs in the motor-fuel sector meets the blending targets. This subsidy stimulates biofuel production to a level consistent with the blending requirement. The biofuel/crude-oil blend is then combined with other fuel inputs, capital, labour and other inputs to produce motor-fuels. RED policies are assumed to be budget-neutral from a government point of view which is achieved by counter-financing the biofuel subsidy by an end-user tax on motor-fuels, implying that the motor-fuel user pays for the extra cost involved for using fuel with higher biofuel blending rates.

The byproducts of biofuel production (DDGS and BDBP) are demanded by the livestock sectors where they compete with wheat, other grains, oilseeds and other compound feeds to make the concentrated feed that is an alternative to grassland (roughage) feeding. The market price for the feed byproducts ensures that the demand for the products equals to their supply.

5.1.3 Macroeconomic assumptions and RED and REDD scenarios

The evolution of the economy with RED and REDD policies in place is projected for the period 2010-2030 and compared with the evolution of the economy without these policies (the business-as-usual scenario). The business-as-usual scenario shows a future that follows

[16] See Horridge *et al.* (2013) and Harrison *et al.* (2012).

the GDP and population projections of the USDA (see the first two rows of Table 8). A pre-simulation is run to derive the overall country-wide technological change consistent with the GDP projections (Hertel et al., 2004). The country-wide average rate of technological change is then distributed at the sectoral level using trends for relative sectoral total factor productivity growth. Technological change is assumed to be 3 times the average rate in agriculture, 1-2 times the average in manufacturing, and 0.5 times the average in services (CPB, 2003). All factors except capital are assumed to experience technological change. Capital is exempt as the capital/output ratio has been shown to be roughly constant over long periods of time. Land productivity is assumed to improve following FAO yield projections as shown in row three of Table 8. The projected increases in GDP and population suggest a strong increase in demand for agricultural products and therefore agricultural land use. The MAGNET simulations suggest that the average worldwide real land price will increase by 47.3% between 2010 and 2030. The demand side pressure on land therefore outweighs any improvements in yields.

Table 8. Scenario assumptions

		World	Europe	C&S America	USA	Canada	Southern Africa	Rest of Africa	Former Soviet Union	China	Southeast Asia	Indonesia	Oceania	Rest of Asia
All scenarios	GDP[1]	100	50	118	76	72	169	143	138	305	150	154	83	90
	Population[1]	21	-1	22	18	14	28	50	-4	8	24	19	24	28
	Yields[2]	39	20	32	19	21	44	64	17	55	30	31	28	44
RED	Biofuel share 2010[3]	-	1.7	[4]20.6 2.1	3.0	1.4	0	0	0.1	1.1	1.2	0.1	0.8	0.3
	Biofuel share 2020	-	10	[5]25 10	15	3	-	-	-	15	5	12	3	[6]20 5
REDD	Land availability [7]	-35	-4	-53	-32	-82	-30	-9	-56	-10	-71	-55	-22	-2

[1] Growth over the period 2010-2030 (USDA, 2010)
[2] Average growth over the period 2010-2030, weighted by land area (Bruinsma, 2003)
[3] Percentage of first-generation biofuels in transport fuel (Europe = EU27), simple average over countries in each region. (Calculations based on Sorda et al. (2010))
[4] 20.6% in Brazil, 2.1% in Rest of South America
[5] 25% in Brazil, 10% in the Rest of South America
[6] 20% in India, 5% in Japan
[7] Percentage change in potential land availability due to forest and woodland conversion restrictions (IMAGE model calculations, Stehfest et al. (2010))

In addition to the macroeconomic and technological trends, crude oil prices are also included in the business-as-usual scenario as they are a key determinant of biofuel production. These prices are assumed to be largely driven by projected future crude oil production as derived from IEA (2008, 2009). Country-specific values for the efficiency of natural resources utilization in crude oil sectors are also derived from crude oil production figures. The figures show a decreasing productivity of natural resources in crude oil sector for almost all regions, which is generally consistent with the observed and expected decline of output from oilfields (IEA, 2008).

The Renewable Energy Directive scenario is implemented as a global mandatory blending requirement. All major economies except Russia currently impose mandatory or voluntary requirements for liquid biofuels. Mandatory requirements for both ethanol and biodiesel are in place in the EU, US, Canada, Brazil, Argentina, Colombia, India, Thailand, Indonesia and Philippines. Paraguay and Ecuador employ an mandatory ethanol mandate, whereas Uruguay has a mandatory biodiesel mandate. China, Japan and Australia set voluntary targets for biofuel production.

The targets are set at different levels and formulated differently in each country or region. The US mandate is volume-based, requiring 36 billion gallons of fuel from renewable sources to be used in US transportation by 2022, whereas the EU and Canadian mandates are share-based. The EU mandate requires a 10% share of biofuels in transport fuel by 2020 and the Canadian mandate required 5% renewable content in gasoline-based motor-fuels by 2010 and 2% renewable content in diesel fuel and heating oil by 2012. Other countries implement their renewable energy targets through the biofuel-gasoline blend available at the pump. For instance, the Brazilian target for 2013 is E25, reflecting a 25% ethanol to 75% gasoline mix, and in Indonesia the mandatory level of biofuels consumption is planned to increase to E15 and B20 by 2025 to reflect a 15% and 20% share of ethanol and biodiesel respectively.

The shares of biofuels in transport fuel implied by these targets are given in Table 8. The starting shares in 2010 are small for all regions except USA (3%) and Brazil (21%). Moving from these starting shares to the RED scenario targets requires, in most cases, a large increase in the share of biofuels in transport fuel. To achieve the RED target, the biofuel share in Indonesia must increase 120-fold, due to the small initial share. This compares with a smaller increase in Brazil from 20.6% to 25%. These targets for using biofuels in the transportation sector are assumed to be achieved by 2020 and maintained up to the end of the simulation period in 2030.

The REDD scenario is introduced as reductions in the maximum amount of land available for agricultural production as presented in Table 8. This reflects the REDD objective to limit conversion possibilities from forestry to agricultural land to protect forests and woodland. The reduction in land availability ranges widely from 2% in Asia and 4% in Europe, to 71% in Southeast Asia and 82% in Canada due to the varying global distribution of forests and woodland. The REDD policy to restrict forest and woodland conversion is assumed to take place at the start of the simulation period i.e. between 2010 and 2013.

The specification of the macroeconomic projections and RED and REDD policies result in three scenarios that are introduced incrementally:

BAU scenario: business-as-usual baseline scenario

RED scenario: BAU plus the global RED scenario

REDD scenario: RED plus strict REDD scenario to protect forests and woodland

A comparison of the RED and BAU scenarios allows the impact of the biofuel policy to be quantified and a comparison of the RED and REDD scenarios captures the effect of the forest protection policy.

5.1.4 Consequences of RED and REDD policies for land use, food security and trade

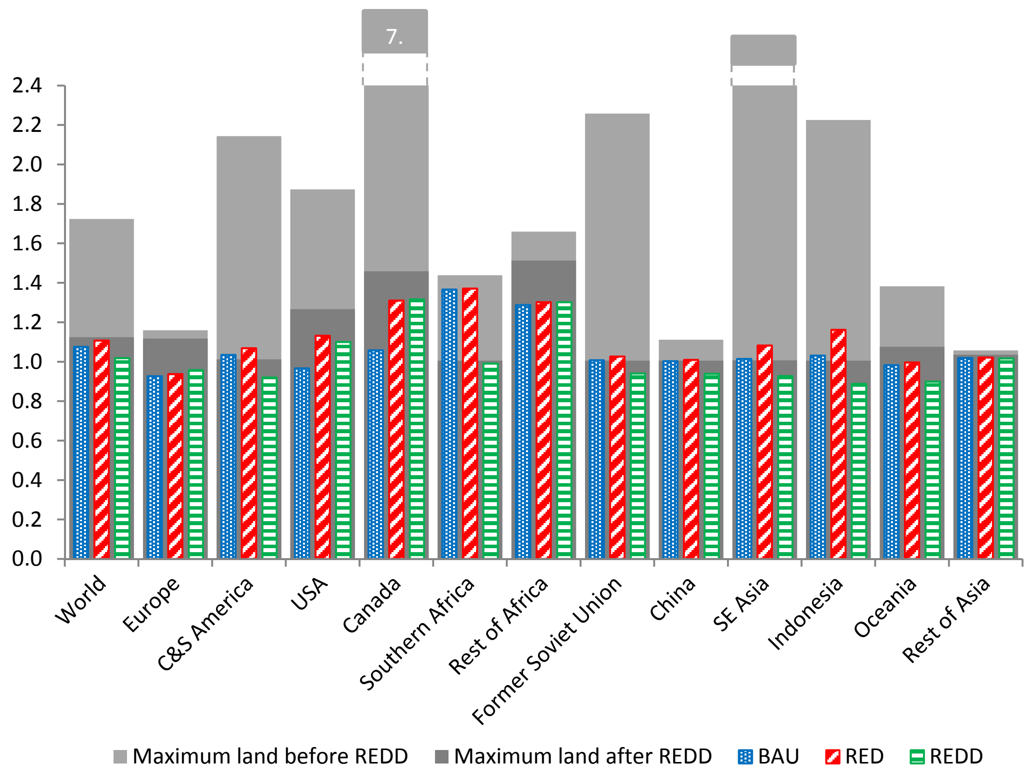
In assessing the interaction of global renewable energy directives (RED) and the REDD programme to limit deforestation and forest degradation, we find that economic and population growth, together with biofuel policies, increase the demand for agricultural products and agricultural land use. The increased demand for land is met by increased yields and the conversion of forests and woodlands. The introduction of a REDD policy to protect forests and woodlands, limits the supply of land suitable for agricultural production, leading to the intensification of production and higher land prices.

These headline results are shown at the regional level in Figure 22. The business-as-usual scenario suggests agricultural land use will increase by 2030 in all regions except Europe, USA and Oceania. Southern Africa and the Rest of Africa experience particularly strong increases of 37% and 29% respectively. The introduction of RED policies increases agricultural land use in all regions as the additional demand for biofuel feedstocks leads to strong increases in land demand. The area under cultivation due to RED in Canada is 24% higher than the baseline value in 2030, 17% in the USA and 13% in Indonesia. These regions are all land-abundant. The limited nature of Canada's biofuel policy indicates that the observed effect is a trade effect. The results suggest that the RED policies have a limited effect on land are Southern Africa and Rest of Asia (both 0.3 per cent). The average worldwide increase in agricultural area is 3% following the introduction of RED.

In many regions, the agricultural land expansion brought about by renewable energy directives is achieved at the cost of deforestation. This happens to a great extent in Southern Africa, Southeast Asia and Indonesia and to a lesser extent in Central & South America and in Russia and the former Soviet Union countries. This pattern is consistent with currently observed trends which show major losses (more than 0.5% annually) in the tropical forests of West and East Africa, South and Central America, and Southeast Asia.

The implementation of the REDD policy to protect forests and woodlands leads to significant decreases in agricultural land availability as shown by the reduction in the height of the land-availability columns as we move from the RED to REDD in Figure 22. This reduction in land availability reduces total land under cultivation by 6% compared with the business-as-usual scenario and by 8% compared with the RED scenario. The largest reductions in land area occur in regions where the land restrictions are binding. Land use under REDD is 28% lower in Southern Africa relative to the RED scenario, 24% lower in Indonesia, and 14% lower in Central & South America and Southeast Asia. Europe and Canada experience small increases of less than 2% in the amount of land under cultivation.

Figure 22. Agricultural land use in 2030 (2010=1) and maximum available land relative to 2010 land under cultivation (2010 land under cultivation equals 1)

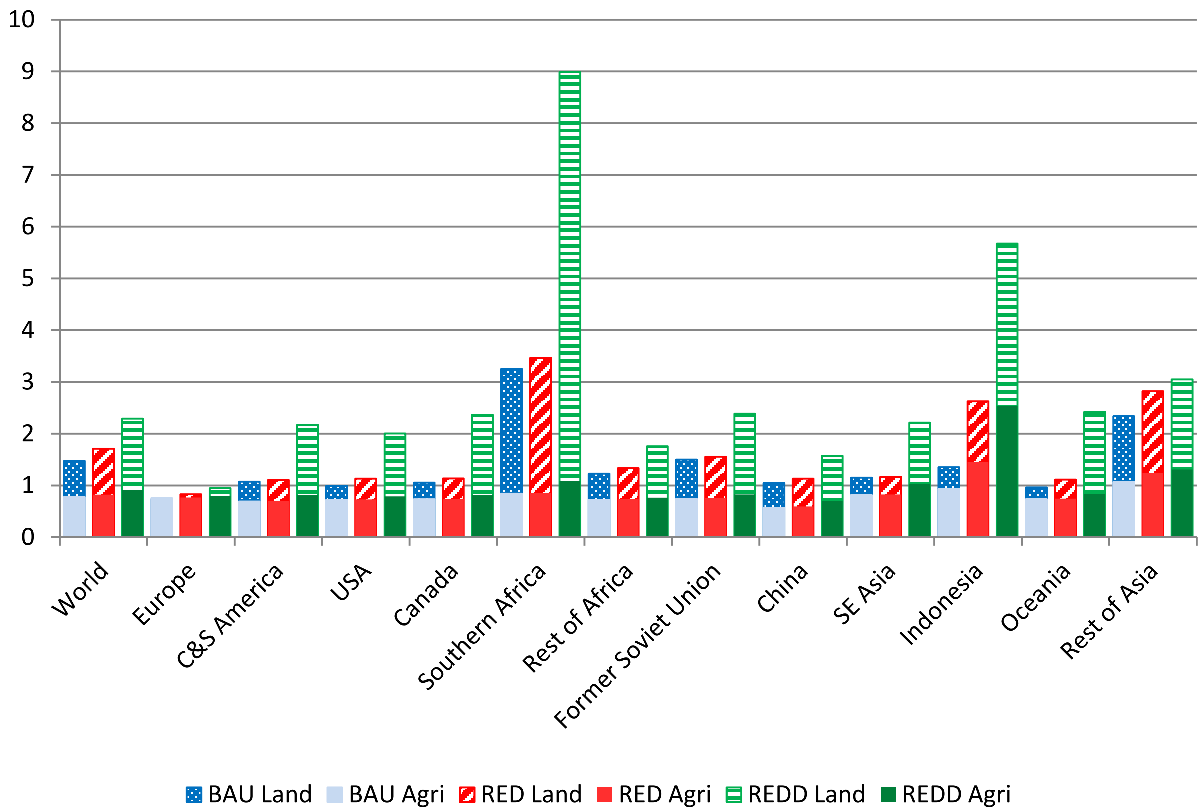


Note: The y-axis is truncated due to space and the numbers provide the ratio of land availability to land under cultivation in 2010 before REDD in Canada (7.9) and Southeast Asia (3.5). If a column is higher than the dark grey horizontal line, the expansion of agriculture is only possible by converting forest or woodland into agricultural land.

Source: MAGNET model simulations.

Large reductions in land use are brought about by significant increases in real land prices following the restrictions on the amount of available agricultural land. The change in real land prices and their impact on agricultural prices are shown in Figure 23. The impact of the REDD policy on land prices is particularly pronounced; increasing land prices in all regions. The average land price increase under REDD is 56% higher than in the business-as-usual scenario, and 34% higher than in the RED scenario. That is, instead of increasing by 47% as in the business-as-usual scenario, the average real land price increases by 71% under the RED policy, and by 129% under the REDD policy.[17] There is a high degree of regional variation depending upon the scale of forest and woodland protection relative to current land use levels. Land prices in Southern Africa, for example, are 160% higher after the introduction of the policy to protect forest and woodlands, compared to the land price under RED. Land prices also more than double in Canada, Indonesia and Oceania. The smallest land price changes are observed in Europe (15 per cent) and Rest of Asia (8 per cent) due to the relatively small reductions in land availability of 4% and 9% respectively in these regions.

Figure 23. Real land prices and agricultural producer prices in 2030 (2010=1, overlaid bars)



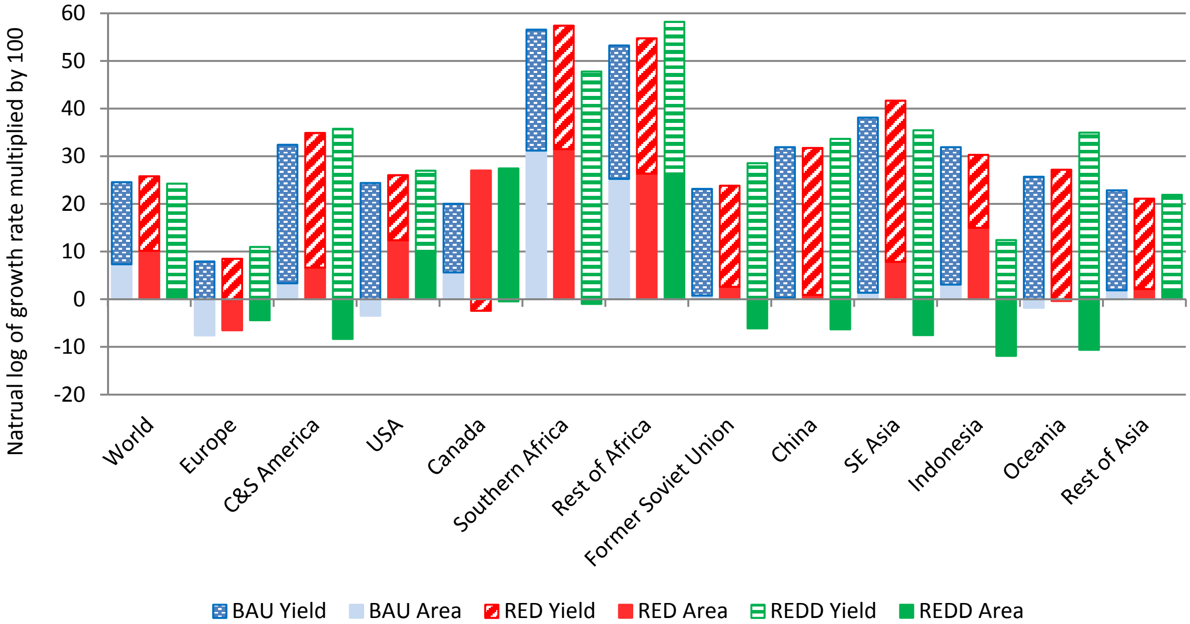
Source: MAGNET model simulations.

Although agricultural prices are generally projected to fall over the period in all scenarios, higher land prices lead to relatively higher agricultural prices after the introduction of RED policies and higher still after the introduction of the REDD policy (see Figure 23). The impact of changes in the land price on agricultural prices depends upon the share of land in agricultural production. Regions that favour extensive agriculture, and therefore use a large amount of land to produce agricultural products, experience greater impacts on agricultural prices than regions with intensive agriculture for which land costs are a smaller share of production costs. The combination of strong land price rises and extensive agriculture

[17] Note: 2.29/1.47 = 1.56.

actually reverses the trend in falling agricultural prices for four regions: Southern Africa, Indonesia, Southeast Asia and Rest of Asia. Each of these regions has land costs that comprise more than 20% of total agricultural production costs. The price rise is particularly strong in Indonesia, such that agricultural prices are 74% higher after the introduction of the REDD policy than with the RED policies alone.

Figure 24. Decomposition of percentage change in agricultural output by land area and yields, 2010-2030



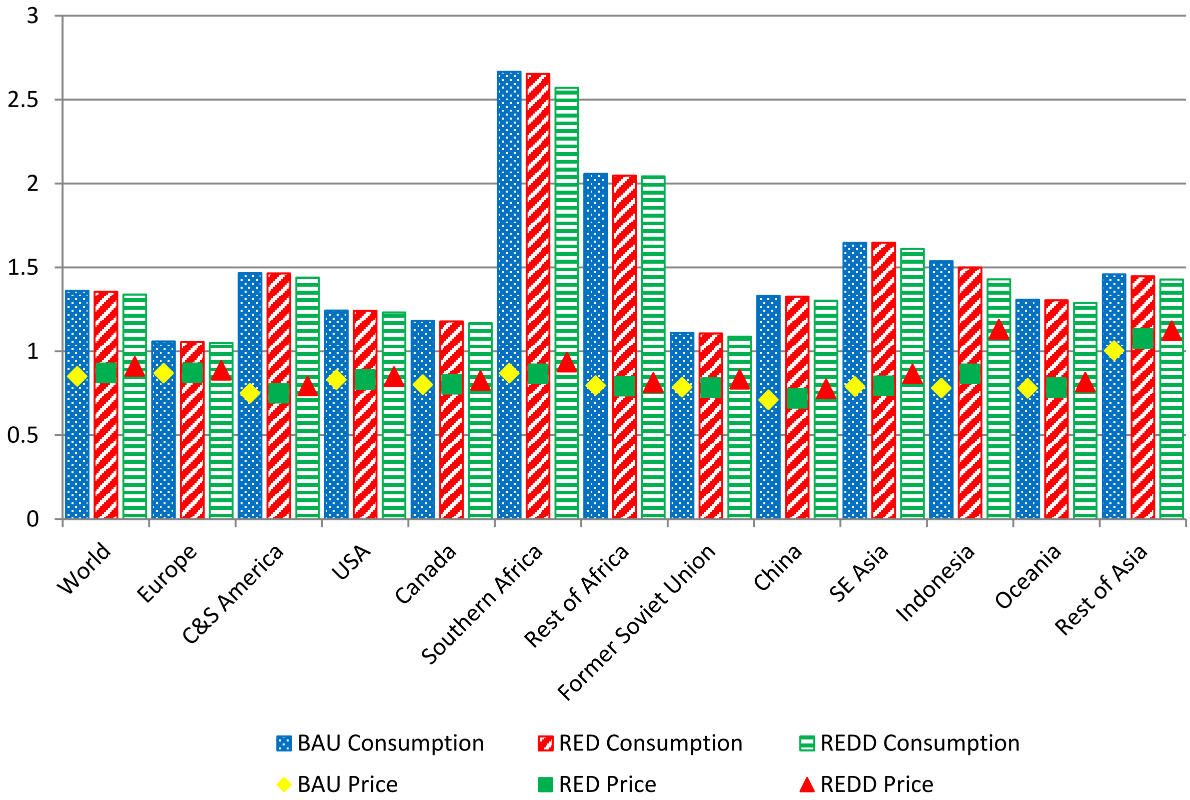
Source: MAGNET model simulations.

The introduction of restrictions on available land for agriculture leads to an intensification of agriculture. Intensification occurs when the land price rises relative to the prices of capital and labour causing more units of capital and labour to be employed per unit of land. The intensification and extensification effects of changes in agricultural production between 2010 and 2030 are shown in Figure 24. Globally, the 28% expansion in business-as-usual agricultural production is achieved by an 8% growth in land area and 19% growth in yields[18]. The introduction of renewable energy directives leads to slightly higher agricultural production growth (29%) brought about by greater extensification of land area (11%), compared with growth in yields (17%). This contrasts with greater intensification under the REDD policy where the increase in production of 28% is achieved by significant yield growth of 25% and only 2% land area expansion. The most pronounced exception to this trend is Indonesia where the RED policy changes the land use from more productive animal production to arable which causes yields to decrease.

The results so far suggest that the introduction of the UN REDD policy to protect forests and woodlands will lead to an intensification of agriculture coupled with higher agricultural prices. The implications of these higher agricultural prices for food security are shown in Figure 25.

[18] Figure 24 shows changes in logarithms multiplied by 100. Thus a 28 per cent increase is shown as 25 [= 100*ln(1.28)]. Use of logarithms avoids having a residual in the decomposition of output growth into the contributions of area and yields.

Figure 25. Consumer food prices and household food consumption in 2030 (2010=1)

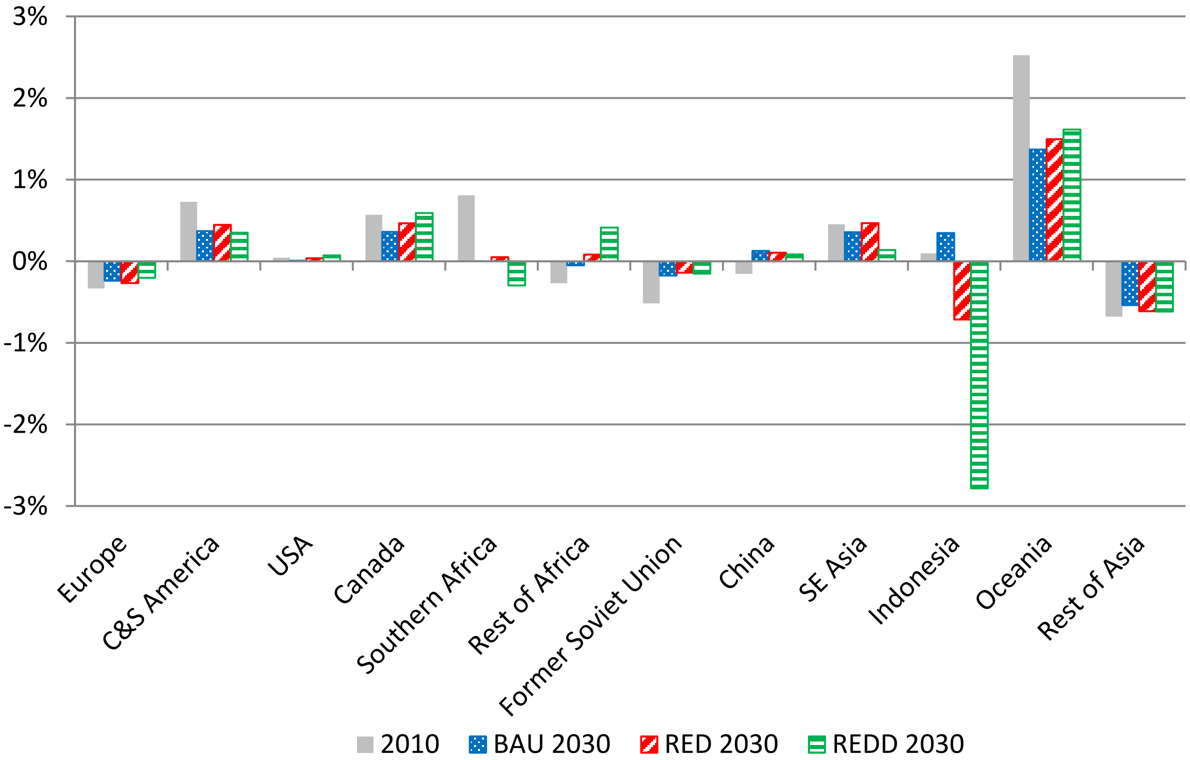


Source: MAGNET model simulations.

The impact of the RED and REDD policies on food security can be evaluated by considering the impact on food prices and food consumption by households, where higher prices and a reduction in food consumption is taken to mean a worsening of food security. On average, the worldwide consumption of food slightly decreases as result of the REDD policy, due to a small increase in consumer prices, however, the impact of the REDD policy is unequally distributed over the regions. Consistent with the large increases in agricultural prices in Southern Africa and Indonesia, consumer prices in these regions are 8% and 31% higher respectively after the introduction of the REDD policy compared with the RED policies alone. This leads to a reduction in food consumption of 3% and 5% respectively, and a worsening of food security in these regions.

The implementation of the REDD policy leads to a slowdown in worldwide agricultural trade as shown in Figure 26. The volume of agricultural exports decreases by 5% following the restriction on land availability. Importantly, two net exporters of agricultural products, Southern Africa and Indonesia, become net importers under the REDD scenario.

Figure 26. Net-export value of agricultural commodities (excluding transportation costs) as a percentage of GDP



Source: MAGNET model simulations.

5.1.5 Implications for Europe

The evolution of the European economy differs from that of the global economy between 2010 and 2030. Large increases in global land demand and land prices contrast with expected falls in land demand and prices in Europe. The results suggest that the demand for land in Europe will be 7% lower in 2030 compared with an 8% expansion in global land demand.

Real land prices in Europe are projected to fall by 27% compared to their 2010 values, in contrast to an expected global increase in land prices of 47%. These trends, driven by economic, demographic and yield growth, are expected to occur despite only 80% of available land in Europe being under cultivation in 2010.

The introduction of global biofuel and forest conservation policies offsets these trends to some extent and provides a boost to agricultural production in Europe. Both policies increase the demand for land in Europe which leads to higher land prices compared to the baseline. Land demand in Europe falls by 6% and 4% respectively between 2010 and 2030 in the RED and REDD scenarios, compared to 7% in the baseline scenario, and European land prices fall by 5% with the introduction of the REDD policy compared to 17% and 27% in the RED and baseline scenarios.

Agricultural production is higher in Europe after the introduction of the biofuel and forest conservation policies. Agricultural production increases by 2% under the RED scenario and by 7% under the REDD scenario, compared to only 0.3% in the baseline scenario. In the case of the biofuel policy, the extra production is absorbed by extra demand from within Europe. In the case of the REDD policy, greater requirements on forest conservation in other regions increase average global agricultural prices by 17%, compared to only 5% in Europe. This causes Europe to have a comparative advantage in agricultural products and boosts agricultural exports, as shown by the improvement in the trade balance in agricultural products.

Overall, Europe appears to experience net gains from global efforts to increase biofuel use and protect forests, experiencing higher agricultural production and trade, with only small increases in land prices and food prices faced by consumers. These gains arise from the long-term trend in the region towards lower land demand and the minimal requirements placed on land conservation in the region from the REDD policy which improves Europe's comparative advantage in agricultural production.

5.1.6 Summary and conclusions

This paper illustrates the battle between renewable energy directives and forest conservation. Both sets of policies are designed to reduce emissions but have opposite land use effects. Global RED policies expand worldwide land use by 3% relative to the business-as-usual projection, with Canada, USA and Indonesia extending their use of agricultural land and expanding production. In contrast, the REDD policy leads to an overall reduction in agricultural production and a 6% decrease in agricultural land use. The RED policies are typically achieved through greater extensification whereas the restriction on available land for agriculture under REDD leads to a greater intensification of agriculture.

Strict REDD policies to protect all forest and woodland particularly in tropical land abundant regions such as Central & South America and Southern Africa, lead to higher land prices which in turn increase agricultural and food prices. The increase in food prices slightly reduces global food consumption and leads to a more significant reduction in food security in Southern Africa and Indonesia. This said, real food prices are still lower than the 2010 level, even with the RED and REDD policies in place. Overall this suggests that RED and REDD are feasible from a world-wide perspective although the results show that there are some regional problems that need to be resolved. The results show that countries directly affected by forest and woodland protection would be the most economically vulnerable when the REDD policy is implemented.

Indeed, the introduction of REDD policies reduces global trade in agricultural products and moves Southern Africa and Indonesia to a net import position for agricultural products. This suggests that the protection of forests and woodlands in these regions reverses their comparative advantage as they move from being land-abundant to land-scarce regions. The full REDD policy setting does, however, foresee providing compensation to these countries to cover their economic losses.

6. Capital

6.1 Will Improved Access to Capital Dampen the Need for More Agricultural Land? - A CGE analysis of agricultural capital markets and world-wide biofuel policies

6.1.1 Introduction

Since 2001, a rapid growth of biofuel production has been observed, driven by high crude oil prices, as well as by growing interest in reducing Greenhouse-Gas-Emissions (GHG). High oil prices encouraged innovations to reduce crude oil consumption and triggered governments all over the world to stimulate the production and consumption of biofuel. To assure a certain level of reduction of GHG emissions, mandatory targets, e.g., in terms of binding blending targets, have been established. These quantitative measures set targets for the share of renewable fuels (biofuel) in fuel consumption. Mandatory, but also voluntary, requirements are currently imposed for liquid biofuel in many major world economies except for Russia, Sorda et al. (2010).

The consequences of biofuel policies on agricultural markets and GHG emissions have been analyzed in numerous papers. The extensive overview of such studies can be found in Rajagopal and Zilberman (2007). As Rajagopal and Zilberman point out, most of these studies focus on simulating the impact of renewable fuel mandates either at national or at global level. The majority of these studies, however, analyze either the impact of the 2009 EU Directive on Renewable Energy (DRE) or the consequences of the 2007 US Energy Independence and Security Act (EISA) or both; e.g., OECD (2008), Al-Riffai et al. (2010), Banse et al. (2008), Hertel et al. (2010).

However, none of the studies simultaneously assess the global consequences of biofuel policies in those countries mentioned above. This is an important shortcoming because regions not covered by these analyses, but implementing biofuel targets, are often very important producers and exporters of agricultural commodities. The important question is: how will biofuel programs in these countries affect agricultural land use in these countries, their future exports in agricultural commodities and how will the world prices of these products respond? These papers also show significant direct and indirect land use changes as a consequence of rapid increase in biomass demand. In most papers impact on other important production factors such as agricultural labor and capital have been noted in the margins. This paper, therefore, addresses how an improved access to capital affects agricultural production and consequently helps to reduce the pressure on land use as a consequence of obligatory biofuel mandate implementation at global scale.

This paper explicitly examines the joint effect of obligatory biofuel mandates in the EU, the US, Canada, Brazil, the Rest of South America, India, and South-East Asia on land, food production, total GHG balance, trade and prices of agricultural commodities. We will also look at how these policies will influence biofuel production in regions where biofuel targets are voluntary, e.g., China, Japan, Australia and New Zealand.

6.1.2 Biofuel policies

The wide range of policy instruments is used to encourage and support biofuel production; FAO (2008), Rajagopal and Zilberman (2007), Sorda et al. (2010). Since biofuel production is not profitable in all countries, with the exception of Brazil, it has to be supported to become competitive. This is done by applying such policy instruments as subsidies and tax exemptions. Other forms of support include the policy measures influencing the biofuel supply chain directly or indirectly via subsidies for technological innovation, production factors subsidies, government purchases and investments in infrastructure for biofuel storage, transportation and use. Also, tariff barriers for biofuel are often implemented to protect domestic producers. These policy measures stimulate biofuel production but do not assure meeting a production level required to, e.g., meet certain GHG emission reduction targets. Therefore, many countries set targets – biofuel blending mandates – for the share of renewable fuels (biofuel) in fuel consumption.

The mandatory but also voluntary requirements are currently imposed for liquid biofuel in all major world economies except for Russia. In the EU, the US, Canada, Brazil, Argentina, Colombia, India, Thailand, Indonesia and the Philippines, the mandatory requirements for both ethanol and biodiesel are introduced. Paraguay and Ecuador employ an ethanol mandate and Uruguay and Thailand a biodiesel mandate. The targets are differently formulated in different countries. In the EU, the US, Canada, Brazil, Argentina, Colombia, India, Thailand, Indonesia and the Philippines, mandatory requirements for both ethanol and biodiesel have been introduced. Paraguay and Ecuador employ ethanol mandates and Uruguay and Thailand apply biodiesel mandates. In these countries the targets are set at different levels. In the EU, 10% biofuel in transport in 2020 are obligatory; by 2022 36 billion gallons of fuels from renewable energy must be used in US transportation, while Canadian mandates apply for 5% renewable content in gasoline by 2010 and 2% renewable content in diesel fuel and heating oil by 2012. In the remaining countries targets are mainly set for E10 and B5[19] in 2010 which are supposed to increase over time to E10+ and B20+, respectively. For instance, the Brazilian target for 2013 is E25 and in Indonesia the mandatory level of biofuel consumption is supposed to increase to E15 and B20 by 2025. Also China, Japan and Australia set non-binding targets for biofuel production.

6.1.3 Effects of biofuel mandates: literature overview

The consequences of biofuel policies on agricultural markets and GHG emissions have been analyzed in numerous papers. The extensive overview of such studies can be found in Rajagopal and Zilberman (2007). As Rajagopal and Zilberman point out, most of these studies focus on simulating the impact of renewable fuel mandate at a national or global level. The majority of these studies analyses the impact of the EU Directive on Renewable Energy (DRE) of 2009 or US Energy Independence and Security Act of 2007 (EISA). The first one implements a minimum binding target of 10% biofuel in transport by 2020. According to the second one, 36 billon gallons of renewables must be used in transport fuel by 2022. Below, we present the global results of biofuel mandates implementation presented in selected studies.

The OECD (2008) assessment of biofuel policies analyses the impact of DRE and EISA using the OECD/FAO AGLINK-COSIMO partial equilibrium model of domestic and international markets for major temperate-zone agricultural commodities. It assumes that next to the first, also a second, generation of biofuel will be produced in the EU and in the US in the simulation period 2013 - 2017. Therefore, it specifies lower targets for the first generation of biofuel than in DRE and EISA. For instance, in the absence of second-generation biofuel, the EU 2020 biofuel share is reduced to 8%, of which 6.67% will to be reached by 2017. Under these assumptions, the OECD projects that DRE and EISA implementation will result in increase of total ethanol production by 17% and total biodiesel production by about 75% average in 2013-2017 compared with the baseline projection where biofuel policies are not considered. However, the first generation of biofuel will be responsible only for about 11% of ethanol and 50% increase of biodiesel production. The additional production of first-generation biofuels results in extra demand for feedstock commodities which pushes up prices for these commodities and creates additional demand for land. The most pronounced world price increases are projected for coarse grains (3%) and for vegetable oils (14%). Global crop area increase associated with the first generation of biofuel production is equal to about 3.6 million hectares (0.4% increase compared with the baseline) from which about 1.1 million hectares (0.12% increase compared with the baseline) results from DRE.

An IFPRI study, see Al-Riffai et al. (2010), commissioned by DG Trade of the EU-Commission applies a modified version of a global computable general equilibrium model MIRAGE. It assesses effect of DRE implementation and assumes binding target of 5.6% first generation biofuel used in transport in EU by 2020. According to the simulation results, the DRE causes a global increase of ethanol and biodiesel production by 7.6% and 5.1% compared to the reference scenario. Globally, the biofuel mandate leads to an increase in agricultural land use by 0.03% equivalent to 0.8 million hectares. The calculated emissions balance implied by the European mandate is positive and amounts 13 million tons CO2 equivalent. Sensitivity analysis carried out under different mandatory blending (from 4.65 to 8.6%) shows that saving GHG emission effect is decreasing when the level of the mandate increases since higher blending target results in more pressure on land and consequently use of less efficient land in the agricultural production.

Both assessments presented above calculate quite small direct and indirect land use effects of EU and US biofuel mandates. In contrast, the study by Banse et al. (2008), Dehue and Hettinga (2008) report prepared for the Gallagher Review and the Netherlands

[19] E# describes the percentage of ethanol in the ethanol-gasoline mixture by volume, e.g., E10 stands for fuels with 90% gasoline and 10% ethanol. B# describes the percentage of biodiesel in the biodiesel-diesel mixture by volume; for example, B5 stands for diesel fuel with 95% ('fossil'-)diesel and 5% biodiesel.

Environmental Assessment Agency report by Eickhout et al. (2008a) provides much higher estimates of the agricultural land requirements of the EU mandate. Numbers for the respective studies are about 50, 20-30 and 19-31 million ha. At the same time, Banse et al (2008), using CGE model LEITAP, projects similar increase of the biofuel feedstock prices as OECD (2008). Also a study by Mulligan et al. (2010) shows that crop area changes for a marginal change in demand for particular biofuels produced by different models differ significantly.

Why are projections in land use changes so different in different studies? Edwards et al. (2010) analyzed reasons for these differences and point out that "The major factors causing dispersion of model results are: by-product effects, how much yields increase with price, and how much crop production is shifted to developing countries." The same factors seems to be the underlying causes of the differences in land use changes as an effect of biofuel mandate implementation in different studies. Another reason for these wide-spread results are differences in the assumptions of available land for agriculture. If one assumes a large amount of potential agricultural land, growing land demand for biofuel crops will neither lead to a significant increase in land price nor to a boost on food prices.

As already mentioned most studies mentioned above have a strong focus on land use change changes and do not consider the possibility to intensify the land use by increasing use of capital. Reducing the pressure on land use is one of the main challenges to guarantee the increase of agricultural production for an increasing demand for food, feed, fuel and fiber. Therefore, the analysis presented here shows how an improved access to capital affects agricultural production and consequently helps to reduce the pressure on land use as a consequence of obligatory biofuel mandate implementation at global scale.

6.2 Quantitative Approach

This paper explicitly examines the joint effect of obligatory biofuel mandates in the EU, the US, Canada, Brazil, Rest of South America, India, and South-East Asia on land, food production, total GHG balance, trade and prices of agricultural commodities.

6.2.1 Database

The analysis is based on version 6 of the GTAP data, Dimaranan (2006). The GTAP database contains detailed bilateral trade, transport and protection data characterizing economic linkages among regions, linked together with individual country input-output databases which account for intersectoral linkages. All monetary values of the data are in $US millions and the base year for version 6 is 2001. This version of the database divides the world into 88 regions. The database distinguishes 57 sectors in each of the regions. That is, for each of the 88 regions there are input-output tables with 57 sectors that depict the backward and forward linkages amongst activities.

The initial data base was aggregated and adjusted to implement two new sectors – ethanol and biodiesel – representing biofuel policy in the model. These new sectors produce two products each; the main product and byproduct. The ethanol byproduct is Dried Distillers Grains with Solubles (DDGS) and biodiesel byproduct – oilseed meals (BDBP).

Finally, we distinguish 45 regions, 26 sectors and 28 products. The sectoral aggregation includes, among others, agricultural sectors that use land (e.g., rice, grains, wheat, oilseed, sugar, horticulture, other crops, cattle, pork and poultry, and milk), the petrol sector that demands fossil (crude oil, gas and coal), and bioenergy inputs (ethanol and biodiesel) and biofuel production byproducts. The regional aggregation includes all EU-15 countries (with Belgium and Luxembourg as one region) and all EU-12 countries individually except for the Baltic countries which aggregated to a single region, with Malta and Cyprus included in one region, and Bulgaria and Romania aggregated to a single region. Outside the EU the analysis covers all important countries and regions from an agricultural production and demand point of view.

The extensions with regard to the capital demand have been already outlined in Shutes et al. (2012). The specification of the capital market has been improved through the introduction of capital vintages, sector specific capital or allowing for different types of investment good. Here we implement a sensitivity analysis on the parameters which determine the capital market modelling in MAGNET for the substitution elasticities between capital and other factors as well as the parameters that govern the movement of capital between agricultural and non-agricultural markets.

6.2.2 MAGNET model

The economic model is the MAGNET (Modular Applied GeNeral Equilibrium Tool) model which is a multi-regional, multi-sectoral, static, applied general equilibrium model based on neo-classical microeconomic theory; see Woltjer and Kuiper (2013). It is an extended version of the standard GTAP model, Hertel (1997) and builds on the LEITAP model, see Nowicki at al. (2009) and van Meijl et al. (2006).

The core of GTAP and MAGNET models is an input–output model, which links industries in a value added chain from primary goods, over continuously higher stages of intermediate processing, to the final assembling of goods and services for consumption. Extensions incorporated in MAGNET model includes an improved treatment of agricultural sector (like various imperfectly substitutable types of land, the land use allocation structure, land supply function, substitution between various animal feed components), agricultural policy (like production quotas and different land related payments) and biofuel policy (capital-energy substitution, fossil fuel – biofuel substitution). On the consumption side, dynamic CDE expenditure function was implemented which 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 agriculture and non-agriculture labour and capital was introduced.

This paper mainly refers to options to modify a) the mobility of factors *within* one sector and b) *between* different sectors. The first option will affect the degrees of substitutability between different inputs in the sectoral production function while the second option will model how easy one factor, e.g. capital applied in agriculture can be transferred to sectors outside agriculture.

Due to the fact that the production technology builds on the assumption of a CES function the standard demand function (qf) for the input i in any sector j and region r can be described by the following equation:

```
qf(i,j,r) = - af(i,j,r) + qo(j,r) - ao(j,r)
- ESUBT(i,j,r) * [pf(i,j,r) - af(i,j,r) - ps(j,r) - ao(j,r)];
```

The input demand is determined by the level of output qo(j,r), the output price ps(j,r) for commodity j and pf(i,j,r) as the price for input i. The parameters af(i,j,r) and ao(j,r) describe the input augmenting technical progress and the change in total sectoral productivity, respectively. The CES-elasticity is defined by ESUBT describing how a change in input price pf(i,j,r) affects the demand for different inputs limited by the substitutability between different inputs. Thus, the intra-sectoral factor mobility is mainly determined by the choice of the parameter ESUBT. For this paper show how a systematical variation of ESUBT will affect the composition of sectoral input demand between.

Intersectoral factor mobility refers to the speed in which factors move between sectors in response to changes in relative returns. Keeney and Hertel (2005) motivate the introduction of segmented factor markets by four observations: the role of off-farm factor mobility in farm incomes, co-movements in farm and non-farm wages, steady off-farm migration and persistent rural-urban wage differentials (Keeney and Hertel, 2005, p6-7). The model includes a variant with a CET function that Keeney and Hertel use and a variant where an econometrically estimated dynamic mobility equation of capital and labour between agricultural and non-agricultural markets is modelled. Capturing these features better represents agricultural factor markets in MAGNET and improves long-term projections by accounting for off-farm factor movements such as labour migration with a substitution of agricultural labour by new invested capital.

Two types of factor markets for mobile factors are implemented in MAGNET: un-segmented, segmented with mobility between the two sectors governed by a CET function. The un-segmented variant follows standard GTAP. The segmented market with CET function variant follows GTAP-AGR as presented by Keeney and Hertel (2005).

The separation of agricultural and non-agricultural markets leads to separate market clearing conditions and different factor prices in the two markets. The segmented factor markets module links to the rest of the model through input or endowment prices (pf) and the factor market clearing condition. The endowment price is defined as the market price for the factor endowment plus any taxes on factor use. As there are two markets for factors in the segmented market (agriculture and non-agriculture), the endowment price is defined as the agriculture market price plus taxes in the agricultural market and as the non-agriculture market price plus taxes for the non-agricultural market. The market price for each factor (pm) is therefore a weighted average of the agricultural market price (pmagr) and the non-agricultural market price (pmnagr).

The standard GTAP factor market clearing condition is replaced with two market clearing conditions in the segmented factor market module: one for agriculture and one for non-agriculture. The market supply of each factor is therefore equal to the demand for each factor across all industries *within* each market. The total supply of each factor is the sum of the supply of each factor in the agricultural and non-agricultural factor markets.

Although there are two distinct markets for mobile factors in the segmented factor markets module, capital can still move between the two markets. Indeed, extra capital needed in the non-agricultural sector must be pulled from the agricultural sector and vice versa. The movement of factors between agricultural and non-agricultural markets is determined by changes in relative prices and an elasticity of transformation (CET function). Figure 27 provides a graphical illustration of two different CET functions with a higher elasticity of transformation presented by CET^2 and a lower one for CET^1.

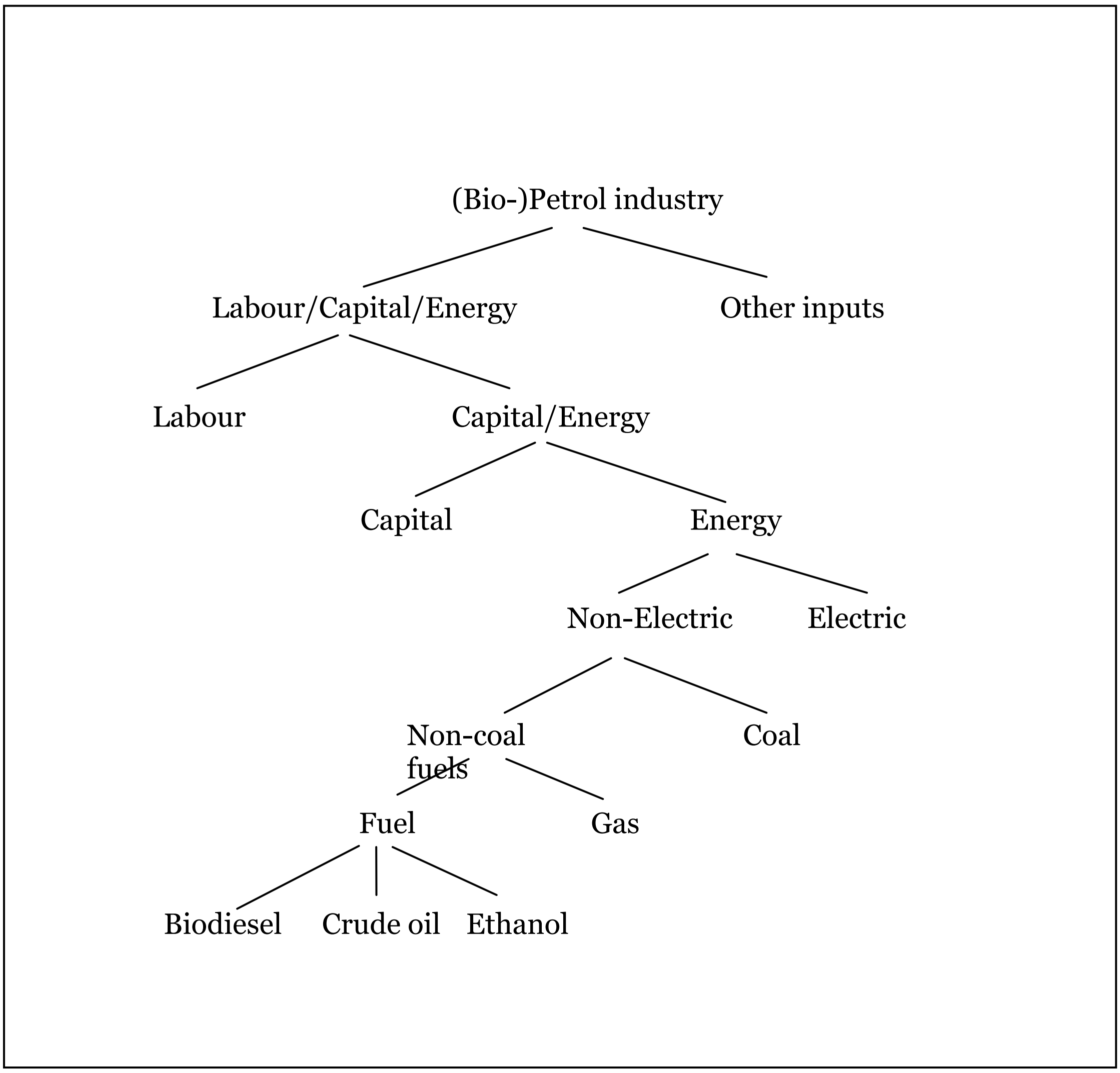
Figure 27. Segmentation of agricultural and non-agricultural capital markets

Under CET[1] the same shift in relative prices for capital in non-agricultural sectors and capital in agricultural sectors from pm'_{agr}/pm'_{nonagr} to pm''_{agr}/pm''_{nonagr} will lead to different responses in the transformation of non-agricultural capital into agricultural capital. With a higher elasticity of transformation, here represented by CET[2] demand for capital in agricultural will expand by $pf^2_{agr} - pf^0_{agr}$ while under a lower level of capital mobility (represented by a lower level of elasticity of transformation) the expansion of capital use in the agricultural sectors will be much smaller.

In the absence of available data on the underlying barriers to factor mobility, Keeney and Hertel (2005) introduce a CET function in GTAP-AGR to 'transform' agricultural capital into non-agricultural capital. This option in MAGNET follows the set up in GTAP-AGR as documented in Keeney and Hertel (2005). The transformation of factors between the two markets is governed by the elasticity of transformation. The transformation elasticity is set at -1 for all factors and regions in the first instance and modified under the systematical sensitivity analysis.

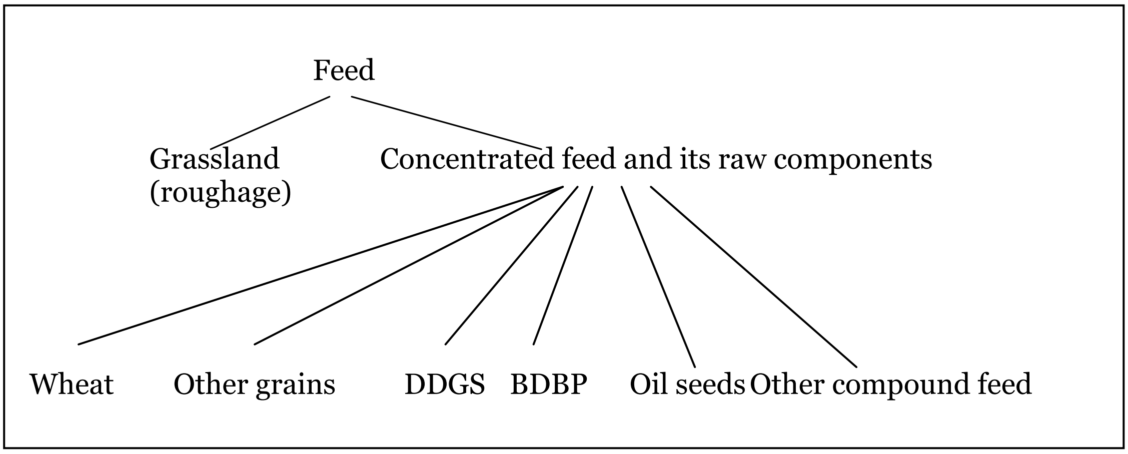
To model biofuel use in the fuel production, we adapt the nested CES function of the GTAP-E model, Burniaux and Truong (2002) and extended it for the petrol sector (Figure 28). To introduce the substitution possibility between crude oil, ethanol and biodiesel, we model different intermediate input nets in the petrol. The nested CES structure implies that biofuel demand is determined by the relative prices of crude oil versus ethanol and biodiesel including taxes and subsidies.

Figure 28. The (bio-) petrol industry nested production structure



The feed byproducts of biofuel production (DDGS and BDBP) are demanded only by livestock sectors in MAGNET. This demand is generated through the substitution process in the feed nest in the livestock sector. In order to model substitution between different feed components and feed byproducts of biofuel production, we use two-level CES nest describing the substitution between different inputs in the animal feed mixture production (Figure 29). The top level describes the substitution possibility between concentrated feed and its components and grassland (i.e., roughage). The lower level intermediate describes the composition of different types of feed commodities (cereal, oilseeds, byproducts and other compound feed).

Figure 29. The animal feed nested structure



6.3 Scenario results

6.3.1 Scenario description

While the main focus on the analysis is on the option to reduce the land use changes under an improved access of agricultural sectors to the capital markets, the main driver in the paper is the introduction of binding biofuel mandates in different regions and countries. The scenario setting is built on a reference scenario (NoBFM) which assumes no mandatory use of biofuel consumption in any part of the world. In addition, we run a single biofuel-policy scenario experiment:

- Glob-BFM Scenario with mandatory biofuel mandate implemented for the EU and the US together with the following countries Canada, Brazil, Argentina, Colombia, Paraguay, Ecuador South Africa, India, Indonesia, Thailand, Philippines.

Based on this setting we use the Glob-BFM as the reference to see how a) an improved substitutability of agricultural land with capital and b) an improved access of agriculture to capital markets ease the pressure on global land use changes induced by world-wide biofuel policies.

6.3.2 Scenario setup

In the biofuel mandate scenario, we fixed the share of biofuels in fuel used in transportation in 2020. To achieve this policy target, a subsidy on bioenergy inputs in the petrol sector increases endogenously to make bioenergy inputs competitive with crude oil inputs. Since this policy instrument is assumed to be 'budget-neutral', these input subsidies are financed by an endogenous user tax on petrol consumption which generates the required funds for the biofuel input subsidies.

The following section will present the results for the reference scenario which does not assume any enforced mandatory blending target. Due to limited space, the impacts of biofuel policies are presented only at the aggregated regional and commodity level.

To show the impact of an improved mobility of capital within and across sectors we applied the following scenarios:

1. CES-CAP: a systematical variation of the **CES elasticity for capital** in the agricultural sectors by -75%, -50%, +50% and +100% relative to the initial level;
2. CET-ALL: a systematical variation of the **CET elasticity for capital and labour** between agricultural and non-agricultural sectors by -75%, -50%, +50% and +100% relative to the initial level and
3. CET-CAP: a systematical variation of the **CET elasticity for capital only** between agricultural and non-agricultural sectors by -75%, -50%, +50% and +100% relative to the initial levels.[20]

The variation of the CET elasticity for all factors (capital and labour) and for capital only should help to identify the impact of an improved inter-sectoral mobility of capital relative to an improved mobility of both capital and labour together. It should be mentioned that for the scenarios analyzing a systematical variation of the CES and CET elasticities each variant of the model have been run twice: one without binding biofuel targets and a second counter-factual with binding biofuel targets under the same level of CES and CET elasticities.

6.3.3 Scenario results

As already mentioned, the main goal is to illustrate the impact of changing factor mobility. However, the next two figures show the impact of a world-wide implementation of biofuel policies on world agricultural prices and land use to give a first glance on the underlying 'scenery'.

Figure 30. Change in real world prices, in percent, 2020 relative to no binding biofuel mandates

Source: Own calculations.

World prices of agricultural products tend to increase with enhanced biofuel consumption as a consequence of biofuel policies. This is especially the case for those products which are directly used as biofuel crops. Figure 30 presents the changes in real agricultural prices relative to a situation without (binding) biofuel policies. Under biofuel mandates international grain and oilseed prices increase by more than 25% relative to the no biofuel scenario.

At the aggregated level total agricultural production increases in the reference and the policy scenario. In all regions, mandatory blending also leads to a moderate increase in total

[20] The results for a variation in the CET elasticities for the capital market only are presented in tables A-1 – A-3 in the annex.

primary agricultural output (see Table 9). Compared with the situation without biofuel policies, the strongest relative increase in agricultural output takes place in the EU and the US itself (EU&US). Here biofuel crop production increases by almost 29% after implementing binding biofuel targets. But also the other regions (Rest-Mandat) where mandatory biofuel policies are implemented face an intensification of agricultural production.

Looking at different biofuel crops, Table 9 presents the results for changes in oilseed production which strongly expands under the policy scenarios. Oilseed production in the EU&US region increases by almost 40% under binding biofuel mandates.

Table 9. Change in agricultural production, in %, 2020 relative to no binding biofuel mandates

	World	All BioF Reg.	EU&US	Rest-Mandat	NoBioF-Reg.
Primary Agriculture	1.4	1.2	2.4	0.2	1.7
Biofuel Crops /1	17.1	18.7	28.6	13.1	13.8
Grains	33.6	37.0	36.9	38.1	27.5
Oilseeds	19.8	19.8	39.8	13.5	19.5

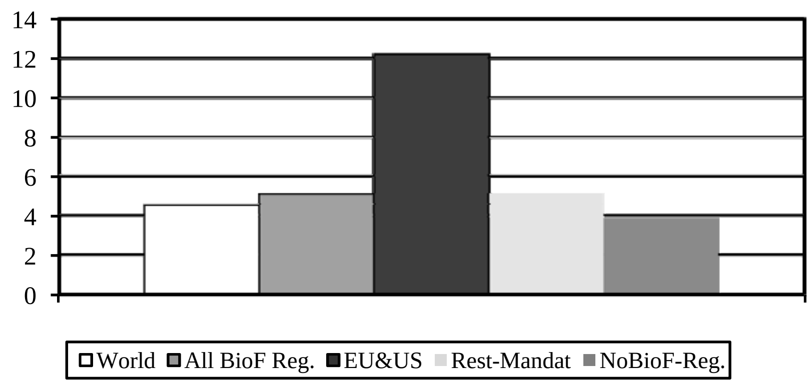
Remarks: All BioF Reg covers all regions listed above with the two subsets 'EU&US' and 'Rest-Mandat'. All other regions that do not apply binding biofuel policies are aggregated under the aggregate 'NoBioF-Reg.'.

/1: This aggregate summarizes total average production change of sugar beet/cane, cereals and oilseeds.

Source: Own calculations.

These production developments lead to a similar pattern of land use developments (Figure 31). Land use increases in all regions compared with no binding biofuel mandates. In the EU and the US, the slight decline in agricultural land use in the reference scenario almost reverses under the EU&US-BFM scenario. As already seen in previous figures, the main drivers in the expansion of agricultural production and land use are the biofuel policies in the EU and the US but also in other regions of the world. With mandatory biofuel policies implemented at global scale agricultural land use increases by around 4.5%.

Figure 31. Change in agricultural land use, in %, 2020 relative to no binding biofuel mandates



Remarks: For explanations of the regional aggregation see remarks for Table 9.

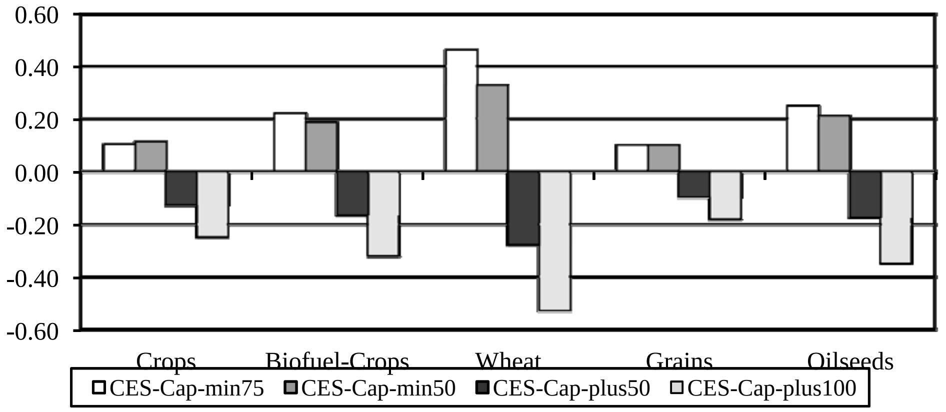
Source: Own calculations.

These results should illustrate the general tendencies after biofuel mandates have been implemented at global scale in different countries and regions. The following graphs show

how the significant impact on agricultural markets in term of price changes, production and land uses might alter, if capital becomes more mobile at intra-sectoral, i.e. within the agricultural sector with a higher substitutability between capital and other factors and at inter-sectoral level, i.e. between the agricultural and the non-agricultural sectors with a higher (factor-) price responsiveness to changes in the ratio capital use within agricultural and the non-agricultural part of the economy.

Similar to the presentation of the general outcome of the implementation of biofuel polices we show the impact on the world agricultural prices.

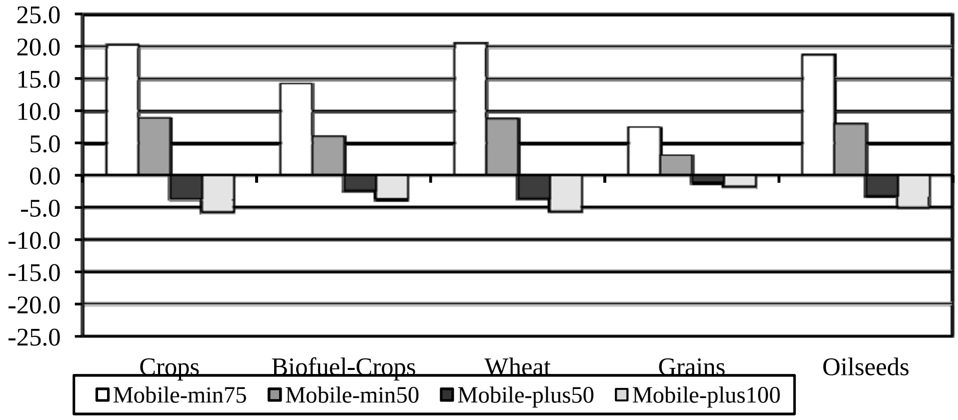
Figure 32. CES Elasticities: Change in real world agricultural prices, in %, 2020 relative to standard CES elasticity values under Glob-BFM Scenario



Source: Own calculations.

A variation of intra-sectoral mobility of capital, due to change in the CES elasticity of capital in the production function has only limited impact on world agricultural prices. With lower CES elasticities which imply a stickier and 'slower' change in the composition of factor use under changing factor prices, world prices of crops used for biofuel production are slightly higher. With higher CES elasticities wheat prices will around 0.5% lower compared with the standard elasticity setting in the Glob-BFM scenario (Figure 32).

Figure 33. CET Elasticities: Change in real world agricultural prices, in %, 2020 relative to standard CET elasticity values under Glob-BFM Scenario



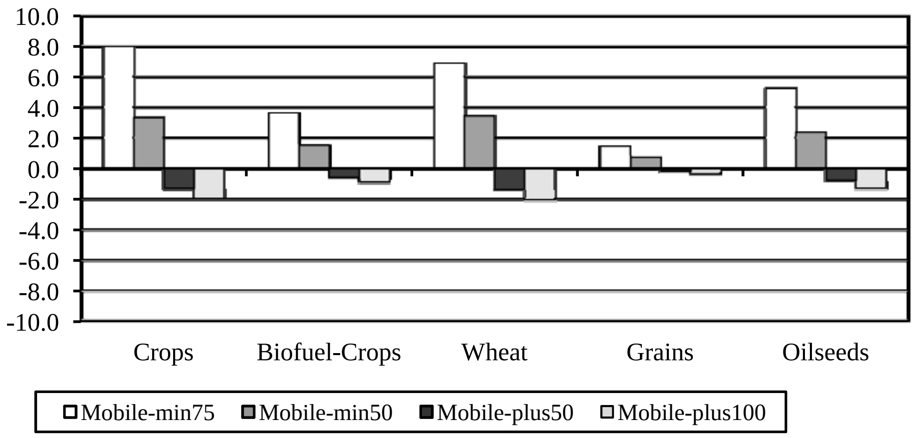
Source: Own calculations.

If we assume an increase in inter-sectoral mobility of factors between agricultural and non-agricultural sectors, the impact of world agricultural prices become more evident. With lower inter-sectoral factor mobility we see that for all arable crops used for biofuel production world prices are much higher compared with the standard CET elasticity values under the Glob-BFM scenario (Figure 33). Under CET elasticities which are 75% lower compared to the standard assumptions world prices for wheat are more than 20% higher. Higher inter-sectoral factor mobility will dampen the increase on world prices and with CET elasticities twice as higher compared to the standard setting wheat prices will be more than 5% lower compared to the standard assumptions under the Glob-BFM scenario.

How do these results correspond to the changes in agricultural production? Under a lower inter-sectoral we observe a higher level of agricultural prices than under the standard assumption. The following Figure 34 shows the impact of a systematical variation in the CET elasticities on the level of agricultural production. The higher level of prices under the lower inter-sectoral mobility is mirrored by higher agricultural production level which is at first sight a little bit counter-intuitive. Lower-intersectoral mobility means lower use of labour and capital compared to the standard scenario outcome. This is, however, only a part of the full picture! In agriculture land is sector-specific and acts as the limiting factor to agricultural production. With higher prices land rents also increase and it becomes profitable to expand land use, see Figure 35. Under lower factor mobility agricultural production becomes more land-intensive and less labour/capital-intensive. Hence land use increases dramatically at global scale.

The asymmetric figure of price change, i.e. higher increases in prices/production under low factor mobility and relatively lower decreases in prices/production under higher factor mobility is due to the sector-specificity of land in agriculture where for most arable crop products land rents are the largest part in total value added and the mobile part of labor and capital gains only a relatively small share in total value added in arable crop production.

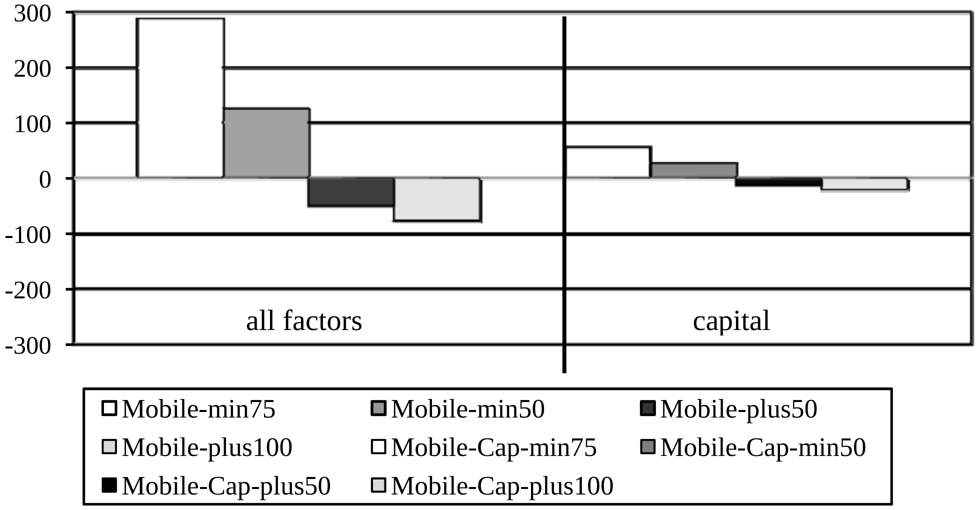
Figure 34. CET Elasticities: Change in world agricultural production, in %, 2020 relative to standard CET elasticity values under Glob-BFM Scenario



Source: Own calculations.

With lower inter-sectoral factor mobility agricultural land use expands as a consequence of biofuel mandates implemented a global scale by almost 290 mill. ha which is equivalent to 5.4% of global agricultural land use. Higher inter-sectoral factor mobility will ease the pressure on expanding agricultural land use and around 80 mill. ha will used less compared with the standard assumption of factor mobility. Here employment and capital use in agricultural increases. If the inter-sectoral factor mobility is altered for capital only, effects become much smaller, (see right hand side in Figure 35).

Figure 35. CET Elasticities: Change in agricultural land use, in mill ha, 2020 compared with standard CET elasticity values under Glob-BFM Scenario



Source: Own calculations.

6.4 Conclusions

This paper shows the consequences of different degree of factor mobility in agricultural production under the assumption of an enhanced biofuel production in those regions and countries of the world which have implemented biofuel policies in terms mandatory blending targets of transportation fuels. The chosen quantitative modelling approach is the multi-sectoral economic MAGNET model with a systematical variation of the inter-sectoral and intra-sectoral factor mobility.

The simulation results of the model show that biofuel policies have a pronounced impact on the markets for grains, oilseeds and sugar, but a rather limited impact on the production level of aggregated primary agricultural output. At the global level, the EU and US biofuel policies contribute to the increasing demand for biofuel crops. But other countries, such as Brazil, Canada, India, Thailand, Philippines and South Africa, that also introduced mandatory biofuel targets contribute to an even higher extent to increasing world prices for agricultural products driven by food use for fuel.

With increasing agricultural output, total agricultural area is projected to increase by 5%, while production of biofuel crops increases by around 19% indicating a more intensive production of biofuel crops at the global level. Even the strong increase in crop production in countries implementing biofuel policies exceeds domestic supply, and the imports of these biofuel crops from other parts of the world which do not implement biofuel policies are projected to increase significantly.

The analysis shows that apart from direct effects of an enhanced demand for bioenergy on production and land use, the indirect effects of biofuel policies dominates. Additional production of biofuel crops within and outside countries with voluntary and mandatory biofuel policies leads to strong indirect land use changes and associated GHG emissions.

The systematical variation of factor mobility indicates that the 'burden' of global biofuel policies is not equally distributed across different factors within agricultural production. Agricultural land as the pre-dominant and sector-specific factor is regardless of different degree of inter-sectoral or intra-sectoral factor mobility the most important factor and limits the expansion of agricultural production. More capital and higher employment in agricultural will ease the pressure on additional land use – but only partly. To expand agricultural production at global scale requires both land and mobile factors adapted to increase total factor productivity in agriculture in the most efficient way.

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Comparative Analysis of Factor Markets for Agriculture across the Member States

245123-FP7-KBBE-2009-3

The Factor Markets project in a nutshell

Title	Comparative Analysis of Factor Markets for Agriculture across the Member States
Funding scheme	Collaborative Project (CP) / Small or medium scale focused research project
Coordinator	CEPS, Prof. Johan F.M. Swinnen
Duration	01/09/2010 – 31/08/2013 (36 months)
Short description	Well functioning factor markets are a crucial condition for the competitiveness and growth of agriculture and for rural development. At the same time, the functioning of the factor markets themselves are influenced by changes in agriculture and the rural economy, and in EU policies. Member state regulations and institutions affecting land, labour, and capital markets may cause important heterogeneity in the factor markets, which may have important effects on the functioning of the factor markets and on the interactions between factor markets and EU policies. The general objective of the FACTOR MARKETS project is to analyse the functioning of factor markets for agriculture in the EU-27, including the Candidate Countries. The FACTOR MARKETS project will compare the different markets, their institutional framework and their impact on agricultural development and structural change, as well as their impact on rural economies, for the Member States, Candidate Countries and the EU as a whole. The FACTOR MARKETS project will focus on capital, labour and land markets. The results of this study will contribute to a better understanding of the fundamental economic factors affecting EU agriculture, thus allowing better targeting of policies to improve the competitiveness of the sector.
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