# Towards an inclusive and sustainable bioeconomy

## Macroeconomic impacts

Prof. J.C.M. (Hans) van Meijl

Inaugural lecture upon taking up the position of Special Professor of Macroeconomic assessment of the circular and bioeconomy at Wageningen University & Research on 4 July 2019

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DOI 10.18174/498646
ISBN 978-94-6395-086-2

# Towards an inclusive and sustainable bioeconomy

*Macroeconomic impacts*

*Dear Rector Magnificus, colleagues, family, and friends,*

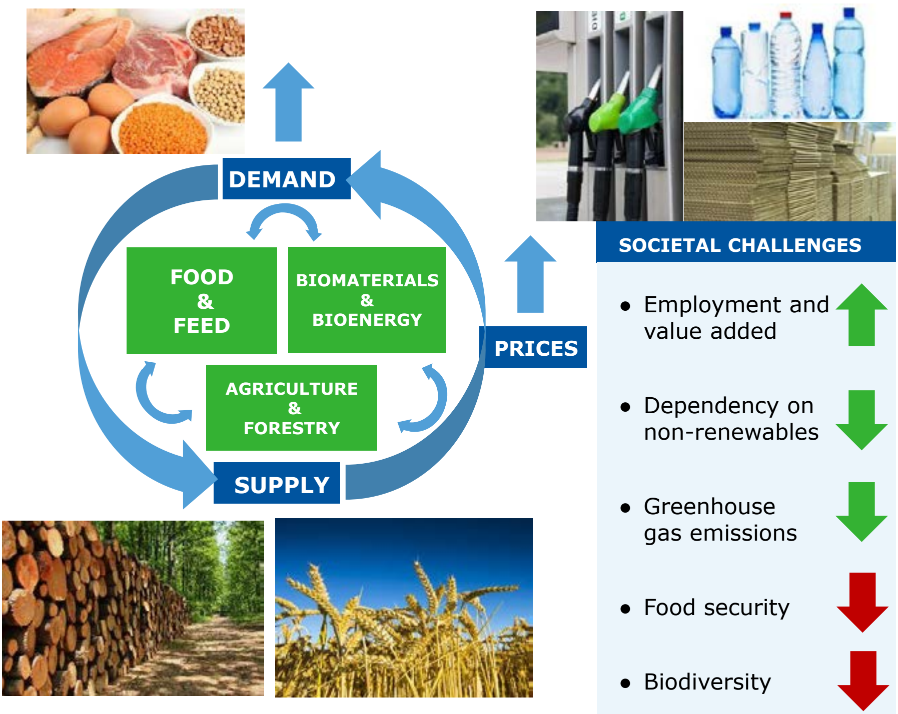
If you see this beautiful running girl you wonder where she is going to?
Why is she smiling?

## 1. Introduction

Have you seen this week's newspapers? It is full about the climate plans of our government, the speed of reducing emissions, the policies to achieve this, the related costs, and who is bearing these costs? Households or industry? BREXIT and Trump's trade war with China, his ideas to tax Dutch Gouda cheese to retaliate for EU subsidies to Airbus put trade policy in the spotlights. What are the implications of all these policies?

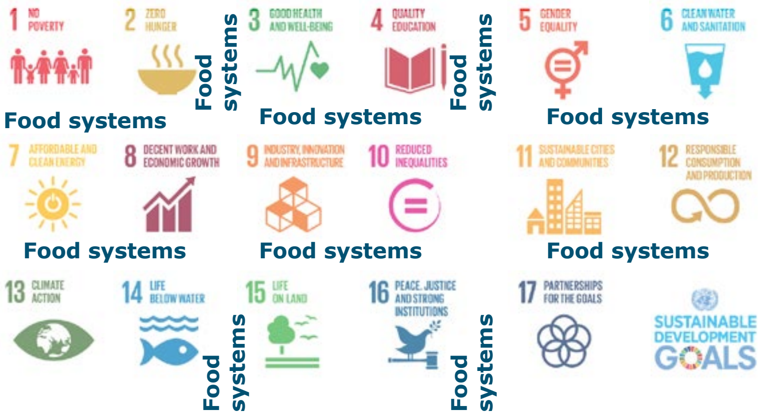
Imagine, instead of reading in the newspaper what policy makers do, you would be the owner of the biomass -cassava- you see in this picture and considering making bioplastics from it to replace fossil resources and to reduce the plastic soup in the oceans. How would you determine the impacts on environment, society and economy? If you started to draw out all the interactions you need to take into account, you will quickly realize how complex this question really is.

Let's explore this example a bit further. Countries across the globe have to produce more biomass feedstock from agriculture and forestry, to meet the growing demand for food and feed, energy, materials, and bio-based chemicals. This has important economic consequences as prices are the result of supply and demand for biomass. A higher demand for biomass, caused by the substitution of fossil energy by biomass, leads to higher prices. This induces higher employment and value added in the bioeconomy. Countries may become less dependent on fossil or non-renewable



resources and emit less greenhouse gasses. But food security and biodiversity might come under pressure as this development competes with land traditionally used for feed and food. So a pretty simple substitution of fossil based by bio-based feedstock has complex implications.

A major societal challenge of the 21st century is *how to feed a growing world population in a sustainable and inclusive manner which strengthens resilience to climate change and incorporates concerns for planetary security.* This challenge is reflected in the United Nations Sustainable Development Goals (UN, 2015) and the Paris climate agreement (UNFCCC, 2016) and requires a growing interest in long-run food and nutrition security.




Here you see the 17 sustainable development goals, focusing on, for example, No Poverty (SDG1), Zero Hunger (SDG2), Health (SDG3), Water (SDG6), Clean energy (SDG7), Decent work and economic growth (SDG8), Reduced Inequalities (SDG 10), Climate Action (SDG 13) and Biodiversity (SDG14 and 15). Food systems are at the heart of all these interlinked challenges. To achieve these goals, decision makers are looking for a coherent set of policies and strategies. Given its complexity an integrated system analysis framework is needed.

In my lecture the common thread will be that my professorship contributes *to an inclusive and sustainable bioeconomy by designing and implementing a system analysis framework, from a macro-economic perspective, that supports coherent policies that address the grand societal challenges.*

After having discussed all elements in this common thread, I conclude with some personal remarks.

## 2. 'address the grand societal challenges'

It is always good to start with the end in mind as I learned from the management guru Stephen Covey (1989). Which mountain do we want to climb? Therefore I focus first on the last part of the common thread '*that address the grand societal challenges*'. I will discuss the 5 grand societal challenges identified by the European Commission's bioeconomy strategy (2012). This builds upon Van Meijl et al. (2017).

**I. Supporting global food and nutrition security for healthier diets**

The first challenge faced by the global food system is to sustainably feed a growing population, which may well rise to more than nine billion people by 2050. Furthermore, people will be comparatively wealthier on average in 2050 and the majority will live in cities. Demand for food, in particular protein from animal sources, is expected to increase proportionally more than the population. In addition we have the triple burden of malnourishment. First, although undernourishment has been on the decline in both relative and absolute terms, nearly 800 million people are still affected by chronic hunger today. Secondly, nearly two billion people suffer from micronutrient deficiencies. Third, more than two billion people are overweight or obese. In other words, around half of the current global population currently faces food-related problems.

**II. Mitigating and adapting to climate change to improve the resilience of food systems**

The 2015 Paris agreement on Climate Change (COP21) agreed that governments should act to keep the temperature rise below two degrees Celsius, and preferably 1.5 degrees at most (UNFCCC, 2016). The longer they wait with policies to reduce emissions radically the higher the chance that we need negative emissions in the future to reach the targets. Agriculture will be affected in three ways. First, climate change impact will affect agricultural production through higher temperature and more extreme events. Agriculture has to adapt to changes in rainfall, temperatures and $CO_2$ levels. Second, agriculture, together with forestry and other land use (AFOLU), is responsible for about 25% of GHG emissions and will need to participate to mitigation efforts. Third, negative emissions options to stabilize the climate might require a large amount of land as afforestation and bioenergy are important options.

**III. Reducing dependence on non-renewable resources towards a circular food economy**

According to the European Environment-State and Outlook report (EC, 2015), total resource use in the EU has declined by 19% since 2007, less waste is being generated and recycling rates have improved in nearly every country. Europe is still dependent on the rest of the world for its essential energy needs. Its total energy import bill is more than one billion euros per day, and import dependency is particularly high for crude oil (more than 90%) and natural gas (66%). The burning fossil fuels accelerates climate change. Despite this, fossil energy subsidies are projected to be US$5.3 trillion in 2015, or 6.5% of global GDP, according to an IMF study (IMF 2015). Such subsidies favour non-renewables in particular. With 17% of the EU's gross energy consumption (equivalent to about 26% of the EU's final energy consumption) in 2013, the agriculture and food sector is a major consumer of energy (JRC 2015).

**IV. Managing natural ecosystems to ensure sustainable food production**
The recent IPBES global assessment report on biodiversity and ecosystem services concluded that 'Nature and its vital contributions to people, which together embody biodiversity and ecosystem functions and services, are deteriorating worldwide' (IPBES, 2019). The biomass of wild mammals has fallen by 82%, natural ecosystems have lost about half their area and a million species are at risk of extinction – all largely as a result of human actions. Important drivers are, in descending order: (1) changes in land and sea use; (2) direct exploitation of organisms; (3) climate change; (4) pollution and (5) invasive alien species (IPBES, 2019). More than a third of the world's land surface and nearly 75% of freshwater resources are now devoted to crop or livestock production. The chemical revolution of the 20th century has encouraged the creation of agricultural systems based on high inputs of energy, fertilisers, pesticides and antibiotics. Although these have brought considerable productivity gains, the excessive use of inputs has also damaged ecosystems. According to OECD farming makes inefficient use of water, accounts for around 70% of water consumed in the world today, and contributes to water pollution from excess nutrients, pesticides and other pollutants (OECD, 2014).

**V. Enhancing agri-food competitiveness to support inclusive growth**
The bioeconomy generates 4.2% of the EU GDP and employs 8.2% of the EU labour force (Ronzon et al. 2017). The ongoing restructuring in agriculture implied a reduction in number of persons employed by 1.5 million between 2008 and 2015. Income disparities have been widening across the world. In OECD countries, the average income of the richest 10% is now about 9.5 times that of the poorest 10%, up from 7 times 25 years ago (OECD, 2013). Income gains accrued disproportionately to top earners between 1976 and 2007, with the highest-earning 1% taking home 47% of total income growth in the United States, 37% in Canada, and 20% in New Zealand, Australia and the United Kingdom (OECD, 2014a).
The labour income share has fallen from 72% to 64% in the 1960-2013 period, changing the functional distribution of income in favour of capital. According to ILO

and OECD technical progress has become biased against labour, especially against low-skilled workers (ILO & OECD, 2015). Furthermore, the Stockholm Statement (2016) finds that technical progress and globalisation favour profits for corporations and the owners of capital over earnings of workers.

## 3. 'to an inclusive and sustainable bioeconomy'

After having discussed the '*grand societal challenges*' we explain the concepts '*to an inclusive and sustainable bioeconomy*' in the common thread.

**Bioeconomy**

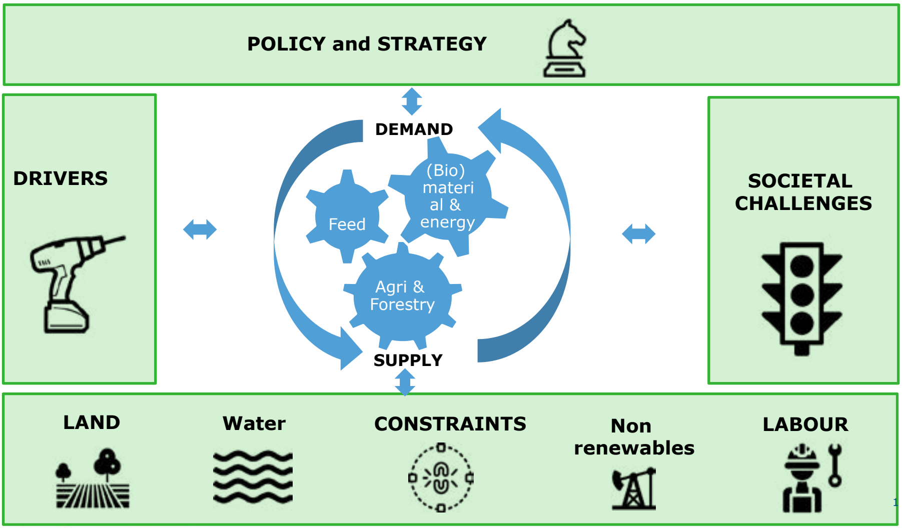
The meaning of the concept has not yet been settled. We use the relatively broad and generic definition of the EC (2012): 'The bioeconomy encompasses the production of renewable biological resources (agriculture, forestry and fisheries) and their conversion into food, feed, bio-based products (pulp and paper, parts of chemical, biotechnical) and bioenergy (fuels, electricity).' The bioeconomy is part of the circular economy that is characterised by a circular, closed flow of materials, where waste from one process becomes an input in another. Circularity is about the reduction, reuse and recycling of raw materials and energy.

**Sustainability**

Sustainable development is a well-accepted concept for European policy. It is anchored in the Treaty of the EU and our policies. When defining this concept, it is important to first take a close look at the word itself. It consists of two parts, namely 'sustain' and 'ability'. At its core the concept of sustainability therefore stands for the ability to sustain. By definition, an unsustainable activity cannot continue indefinitely. The concept of sustainability is essentially a moral declaration as to what should be done. Perhaps the most widely used definition of sustainable development is that of the Brundtland report (WECD, 1987). '*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*' Satisfying the needs of a growing population while ensuring social equity and respecting environmental limits is at the very heart of the concept. This is often formulated in terms of the triple P: people, planet and profit or even better people, planet and prosperity (World summit on sustainable development, Johannesburg, 2002). '*without comprising the ability of future generations to meet their own needs*' implies that we need a long-run perspective and even future generations who do not yet exist are sitting at the table.

**Inclusive**

Inclusive growth creates opportunity fairly across society for all segments of the population and distributes the dividends of increased prosperity, both in monetary and non-monetary terms (OECD, 2017). In sociology, inclusiveness is often defined as the provision of certain goods, such as employment, adequate housing, health care, education and training to a wide range of individuals and groups in society. This is closely related to ensuring social equity. The concept of inclusiveness is bound to the concept of sustainability: satisfying human needs while ensuring social equity are core elements of sustainability. This is supported by the Brundtland Report, which states that sustainable development requires meeting the basic needs of all (WECD, 1987). This refers particularly to meeting the essential needs of the world's poor, and extending the opportunities to satisfy their aspirations for an improved quality of life.




*System analyses framework. Source: Van Leeuwen et al. 2013, Van Meijl et al. 2015, 2017.*

## 4. 'designing ..... a system analyses framework'

The next part in the common tread is '*designing ..... a system analyses framework*'. A system analyses framework or integrated assessment framework might consist of a supply-demand framework that connects the key building blocks; The demand for the circular and bioeconomy comes from a complex linked system of agriculture, forestry, food, feed, wood, energy, chemicals, and other biomaterials, which interacts with the fossil based system. The drivers of the system make the system move by influencing demand and supply. The system drivers economic growth, consumer preferences and demographic growth are identified as key drivers for the demand side, whereas the system drivers innovation and technical change, and climate change are behind the supply side of biomass. The constraints represent limitations to the system such as the amount of available land, water, non-renewable resources and labour. The societal challenges represent the key objectives which are quantified by indicators. These can be the five grand societal challenges or the 17 Sustainable Development Goals. If the indicator shows that the goals are not met, policies and strategies can be undertaken to try to move the system outcomes closer to the policy targets by influencing the demand and supply system drivers.

## 5 'form a macro-economic perspective'

'*form a macro-economic perspective*' is the next part of the common tread I will elaborate upon.

Government has a role in areas where markets do not work well (e.g. environment and health) and where there are clear inclusivity imperatives (e.g. woman empowerment, protection of vulnerable group, and excessive wealth and income inequality). The concept of an inclusive and sustainable economy includes resources which lack adequate markets to manage supply and demand. This can induce the underdelivery of services and/or excess demand, or even overexploitation.

**Internalising external effects**

In economics, an externality, is a cost or benefit that affects a party which did not choose it. Externalities create indirect effects on the consumption and production opportunities of others, as prices of products do not take them into account. Those who suffer from negative externalities, such as in the case of greenhouse gas emissions, do so involuntarily, while those who supply them do so at no cost. The effects are opposite for positive externalities such as innovation and knowledge investments. According to Neoclassical theory this leads to differences between costs or returns to the individual and costs or returns to society as a whole, potentially causing inefficient market outcomes. This involves the overproduction of those linked to negative externalities and underproduction in case of positive externalities. There are many alternative policy options to solve this problem (Coase, 1960). Model based analyses might provide insight into the cost and benefits of the various options.

**Substitution effects**

Many non-renewable resources may soon be depleted if the current extraction rate continues, potentially leading to an economic downturn. Forecasts include the Club of Rome report 'The limits to growth', which already warned about shortages in resources such as copper in 1972 and urged policy makers to take action to remedy the situation (Meadows, et al. 1972). No specific policies were ultimately required, as copper was gradually replaced by other products instead, its use being reduced drastically enough that the predicted shortages never materialised. This demonstrates that a reduction in the quantities of finite resources can be compensated by substitution effects and innovations that draw on human and intellectual capital (Solow, 1986). Likewise, a non-renewable resource that is traded on a market will become more expensive as it becomes scarcer, making substitutes more attractive and inducing innovation. In theory, firms can anticipate this price increase and explore substitution possibilities in good time. In the case of copper, a substitute (fibreglass) was found, and the expected depletion did not occur. In a similar vein, a high oil price will stimulate renewable power and energy saving options. Substitution is frequently underestimated in forecasting.

**Indirect effects**

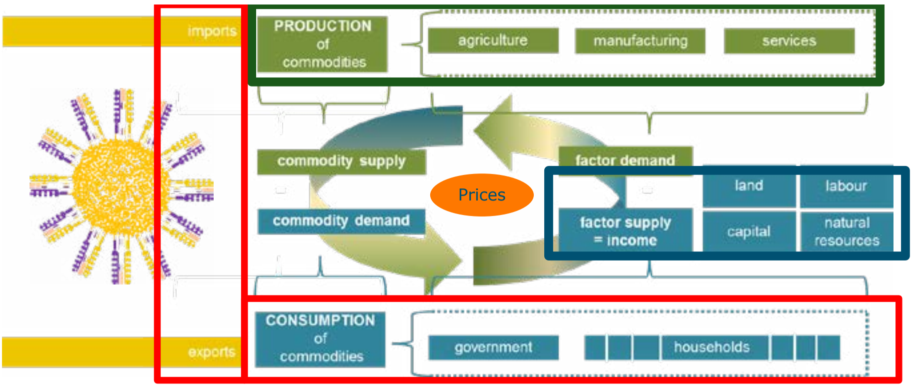
A related principle derived from the field of economics is that the price effect caused by substitution can penetrate (often unexpectedly) into different markets in other parts of the world economy. For instance, the substitution of renewable biomass for non-renewable fossil resources first decreases the demand for fossil resources and induces a lower fossil resource price. This lower price leads to higher fuel consumption in other markets, which partly offsets the initial reduction in fossil fuel consumption and GHG emissions. This is called the rebound effect (Hochman et al. 2010, Smeets et al. 2018).

Moreover, this substitution increases the demand for biofuels and leads to indirect land use change (ILUC), with biofuel crops substituted for food crops (Wicke et al. 2012). ILUC is the change in land use outside a feedstock's production area needed to replace the supply of that commodity and that is induced by changing the use or production quantity of that feedstock. This effect increased land under cultivation in Brazil, which may have caused additional clearing of tropical forests. The transition to environmentally friendly biofuels in European has therefore had environmentally unfriendly effects in South America, which were largely unforeseen while implementing the European policy. Therefore, next to substitution effects these indirect effects need to be assessed and these can be quantified by economic partial and general equilibrium models.

**Macro-economics: Need for new engine of growth**

Let's start with some stylized facts. The Kuznets facts state that there is a massive reallocation of labor from agriculture into industry and further into services (Kuznets 1957). Differences in the demand elasticities with respect to income seem the main explanation. The Kaldor's "stylized facts" state that real output per man-hour and the stock of physical capital per man hour grows at a more or less constant rate. The ratio of output to capital and return to capital show no systematic trend (Kaldor 1957, 1961). Neoclassical growth theory is characterised by factors such as capital and knowledge that can be accumulated and labour, which cannot be accumulated. Crucial in all theories for stable growth is that the marginal product of the factor that can be accumulated does not fall (Van Meijl 1995). However, the factor that can be accumulated is characterised by diminishing returns. Technical change prevent marginal returns from falling and it is exogenous in neoclassical growth theories and endogenous in the new growth theories (Romer, 1986). For a balanced growth in line with the stylized facts of Kaldor technical change has to be Harrod neutral, which means labour saving. In the steady state, income growth is equal to capital growth and equal to consumption growth. The capital-labour ratio and income per head totally depend on technical progress. As technological change is labour saving, say 2% less labour per unit of output, output has to grow by 2% to keep all people employed (without labour growth). Income per capita grows with tech change and this leads to higher consumption. This treadmill implies the continuing increase labour productivity, production capacity, and consumption of a country to keep all people employed.

In Neoclassical growth cases, stable consumption growth drives stable economic growth and this process requires more and more production factors such as land and inputs such materials and energy. Resource and environmental impacts *scale* with economic activity. The need to reduce resources and emissions causes a dilemma with economic stability. Efficiency gains per unit of output are needed but with continuing growth and therefore increase in 'scale' the efficiency gains have to outrun even the scale effect. A new 'green' growth engine is needed based on non-polluting energy and selling non-material services.




**GDP = C+ I + G + X - M**

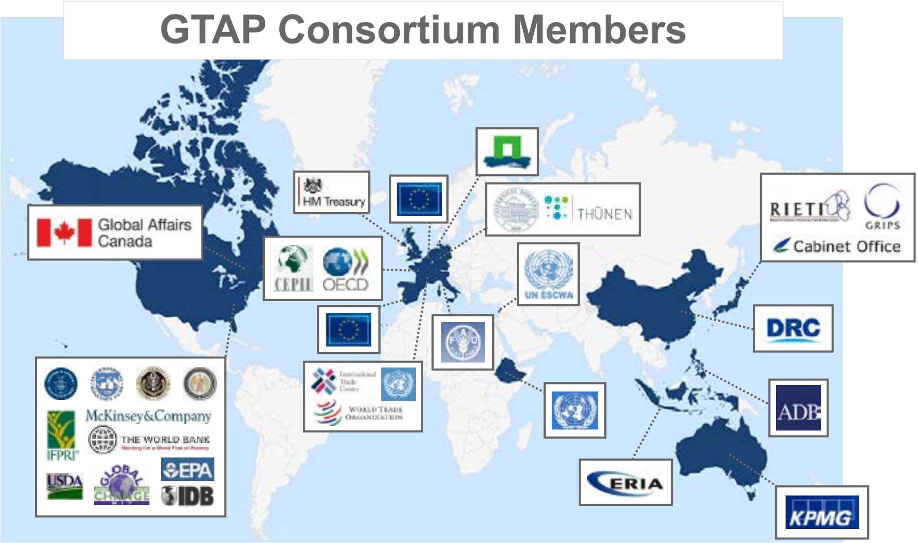
*MAGNET – an economic model of nations in the global economy*

**Macro-economic modelling: Computable General Equilibrium models**
Computable general equilibrium (CGE) models are a class of economic models that use actual economic data to estimate how an economy might react to changes in policy, technology or other external factors. The core of a CGE model is an input–output model, which links industries in value added chains from primary goods, over continuously higher stages of intermediate processing, to the final assembly of goods and services for consumption. Producers are assumed to choose the cheapest combination of imperfectly substitutable labour, capital, land, natural resources and intermediates. In the Figure you see in green at the top the production or supply of all commodities from agriculture, manufacturing and services. At the bottom in blue you see the demand or consumption of all commodities. On the market in the middle supply and demand meet each other and prices are determined. The same is true for the factor markets for labour, capital, land and natural resources.

Within economics GDP is a summary variable and this Figure shows also some of its characteristics. First, it can be measured from the expenditure side as the sum of final expenditures on goods and services. The well-known equation is represented in the red box; GDP (expenditure, aggregated demand) = C (consumption) + I (gross investments) + G (government spending) + X (exports) – M (imports). Second, the sum of all income earned by the production of good and services, within the blue box; GDP (sum of factor incomes) = income from people in jobs and in self-employment (e.g. wages and salaries), profits of private sector businesses, rent income from the ownership of land and natural resources. The third one is the value of output which is the sum of value added from all productive enterprises (in the green box). GDP growth is needed, not as an end in itself but just as a means to create the resources needed to achieve the societal objectives.

## 6. 'implementing a system analyses framework'
The next step in our common thread is to use the system or '*implementing a system analyses framework*'.

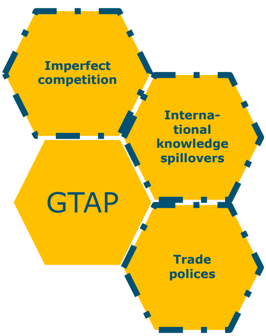
The Global Trade Analyses Project (GTAP) is a global leading consortium in quantitative economic analysis of pressing global concern in the areas of Trade and Development and Global Environmental Issues. It consist of 33 members including OECD, FAO, EC, World bank, IFPRI, *Wageningen Economic Research*, TI, USDA, but also consultancy companies like McKinsey and KPMG. The core of its success is an institutional innovation in economic modelling through international collaboration to increase quality of data and analysis. The idea is to cover together the fixed costs and create a public good to lower entry barriers in this complex field and to better serve policy analysts and decision makers. GTAP is truly a global network with users in




*Global Trade Analyses Project (GTAP), Consortium Members in 2019.*

almost all countries of the world. In the Netherlands we are quite active with 16 users per million inhabitants, mainly representing Wageningen Economic Research and Central Planning Bureau (CPB).


Since 1996 Wageningen Economic Research has been a member of the GTAP consortium and has developed its own Modular Applied GeNeral Equilibrium Model called MAGNET. The MAGNET model is an economy-wide, global, multi-regional, multi-sectoral, applied general equilibrium model based on neo-classical microeconomic theory (Nowicki et al., 2009, Van Meijl et al., 2006, Woltjer et al., 2014). MAGNET has the GTAP model (Hertel, 1997) at its core and 'driven by policy question' the model has been extended with new modules (illustrated by the yellow hexagons) to represent better agricultural features and policies.




**Trade policies and technological change**

From its inception trade policy analyses is at the core of the GTAP model. Also at Wageningen Economic Research the first focus was on trade policies and technological change, and especially international knowledge spillovers and GMOs, which were topics in my PhD. International knowledge spillovers are not perfect and dependent on the absorption capacity, the structural similarity between countries and whether technologies are socially acceptable. A result is that trade protection is more negative as it not only tempers cheaper imports but also the knowledge embodied in these commodities (Van Meijl and Van Tongeren, 1998, 1999, 2004). Based on unique data from empirical micro-level study and field trials of Bt corn and GM maize in China, our results indicated that the welfare gains from the development of biotechnology outweigh the public biotechnology research expenditures. Most gains occur inside China, and can be achieved independently from biotech-unfriendly polices adopted in some industrialized countries (Huang et al., 2004).

Meijl & Tongeren, WA, 1998
Meijl & Tongeren, ESR 1999
Meijl & Tongeren, AE, 2002
Huang, Meijl, Tongeren, JDE, 2004
Francois, Meijl, & Tongeren, EP, 2005
Smeets-Kriskova et al., ESR, 2017

In a Doha trade liberalisation study for the Dutch Ministry of Economic Affairs the model was extended with dynamic effects such as economies of scale in manufacturing sectors and non-tariff measures (Francois et al., 2005). The estimated benefits were $200 billion in case of partial liberalisation and $700 billion in case of full liberalisation. Trade facilitation, agricultural liberalisation, and Manufacturing & Services liberalisation each contribute one third to these results. The study underlined the importance of trade policy reform by developing countries themselves as these contributed 25% of total world benefits. Gains were particularly from liberalizing South-South trade (initial high level of protection). In a recent series of papers we opened the black box of tech change a bit further by including the dynamic effects of an explicit R&D sector that produces factor augmenting technical change (Smeets-Kriskova et al. 2016, 2017a, 2017b).

### Agricultural policies and land use

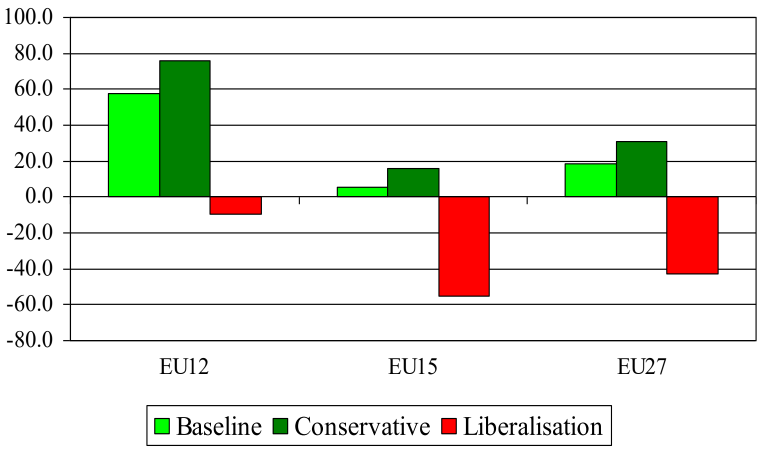
At the beginning of the new millennium, the Dutch Environmental Assessment Agency (PBL) was looking for cooperation to assess both the economic and environmental aspects of policy changes. While land use changes were key in IMAGE model (Alcamo et al. 1998, Stehfest, et al. 2014) in MAGNET they were exogenous as in other CGE models. In a kind of co-creation we developed the innovative land supply curve and empirically underpinned it with IMAGE data (Van Meijl et al. 2006, Eickhout et al. 2007). The linkage of the economic and detailed land use model enabled consistent economic and environmental

*IMAGE model (Stehfest et al. 2014).*

indicators and enabled unique contributions to the OECD environmental Outlook, TEEB (The Economics of Ecosystems and Biodiversity), Global Land use Outlook, and Rio plus20: Pathways to achieve global sustainability goals by 2050. The EUruralis project, in which the IMAGE-MAGNET system was coupled with the land allocation model CLUE and many other environmental indicators of Wageningen Environmental Research enabled a broad perspective and many new developments within MAGNET (Klijn et al., 2015, Rienks, et al. 2008, Verburg et al. 2008).


For MAGNET it implied that in this period agricultural and land use related modules, segmented labour markets, and a specific Common Agricultural Policy (CAP) module were added.

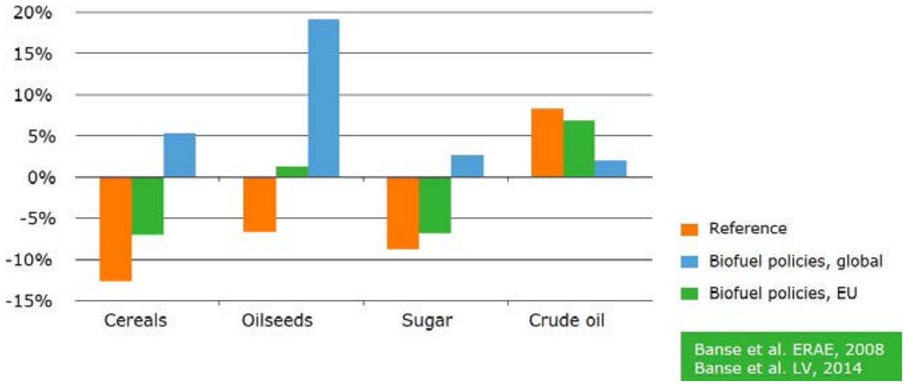
This opened the door for the influential Scenar2020 studies for DGAgri within the European Commission. Wageningen Economic Research assessed key Common Agricultural Policy scenarios for DGAgri. The study concluded that liberalisation would not lead to a huge reduction in agricultural production in the EU, as was often feared, but to a strong decrease in land prices (40%), as you can see in the graph, and severe structural change as the number of farmers would decrease further (Nowicki et al. 2006, 2009, Banse et al. 2008a). So, the CAP was not a policy to secure food production in the EU but a social policy. At the end it was the only impact study mentioned in the new CAP proposal of the EC.




*Scenar2020, Change in Land Prices, EU 2007-2020, in per cent (Nowicki et al., 2009)*

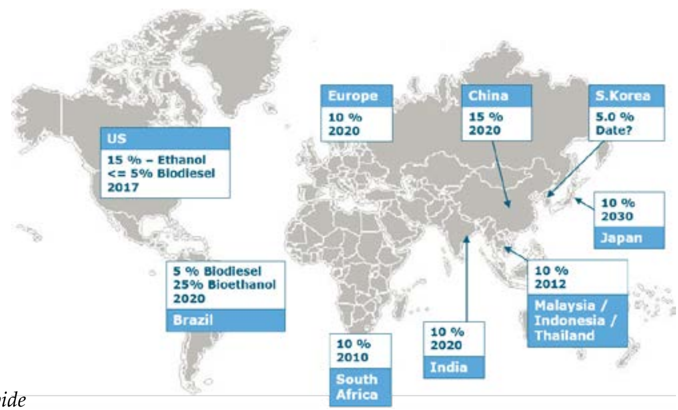
**Bio-based economy**

Early 2000 biofuels entered the agricultural area and the EU biofuel directive of 10% biofuels induced a new policy driven demand category for agricultural products and a direct linkage between the agricultural and energy markets (Banse et al. 2008b, 2011, 2014).




*Impact of Biofuel policies on World Prices (% '01 - '20)*

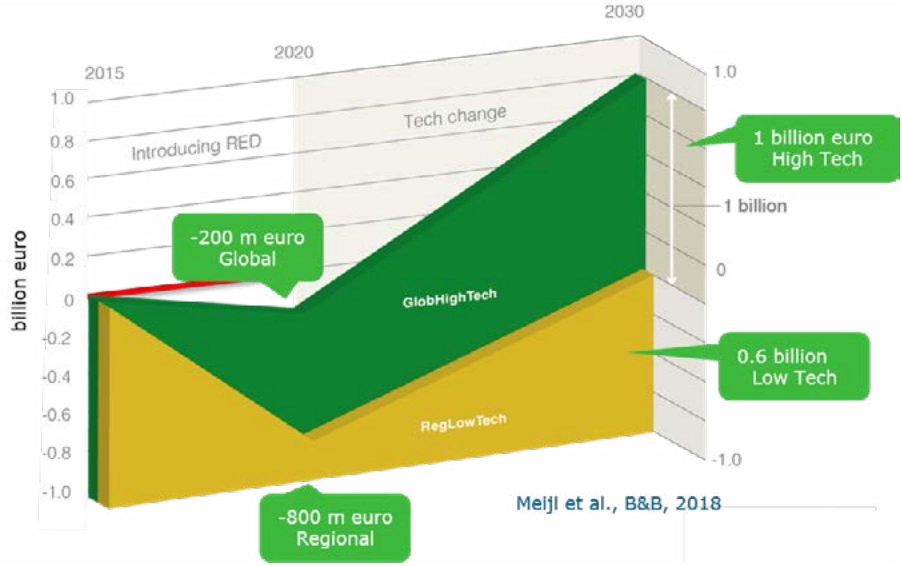
As you can see in this Figure, the orange long-term declining trend in real agricultural prices may slow down or even reverse, when biofuels, represented by the green bars, enter the story. Notice also the little drop in fossil fuel prices as fossil is substituted by biomass, and this will create the earlier mentioned rebound effect (also Smeets et al. 2014). However, not only the EU but many countries were considering biofuels. We assessed that if all the countries would implement their biofuel plans the food prices would increase substantially and the long-term negative trend might be reversed. For example, no decline in cereal prices of 12 % but an increase by 5% (see, blue bars in Figure above). When food prices increased in 2005, first generation biofuels came under pressure in the public debate.




*Targets for Biofuels Worldwide*

We showed that using 2nd generation biofuels based on lignocellulosic materials had less impact on prices and land use.

For the governance of Malaysia we found that especially bio-based chemicals and materials, based on pam oil residues and waste, are a source for value added and reducing dependency on fossil fuels (Meijl et al. 2012).



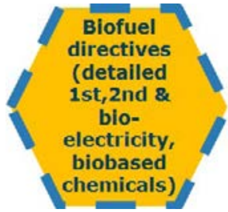

*MEV- BBE: Annual GDP effect of a bio-based economy on GDP in billion euros compared to non-bio-based (Van Meijl, et al. 2016, 2018a).*

In the Macro-economic assessment study for the Dutch biobased Economy Top sector we included first and second generation biofuels, bioelectricity and various bio based chemicals in MAGNET (Van Meijl, et al. 2016, 2018a). The model results showed that short term compliance with the 14% renewable energy targets creates a negative GDP effect of 200 million euro with global sourcing and 800 million with regional sourcing. This is because fossil technologies have to be substituted with more costly bio-based technologies. The recent developments that wind and sun get much more quickly competitive with fossil fuels would have reduced these negative effects. The positive effect of possibly new technology investments becomes only visible after 2020. In the High Tech scenario the benefits for the Netherlands will be 800 million and

Banse et al. ERAE, 2008
Banse et al. B&B, 2011
Banse et al. LV, 2014
Meijl et al. 2012
Meijl et al., B&B, 2018

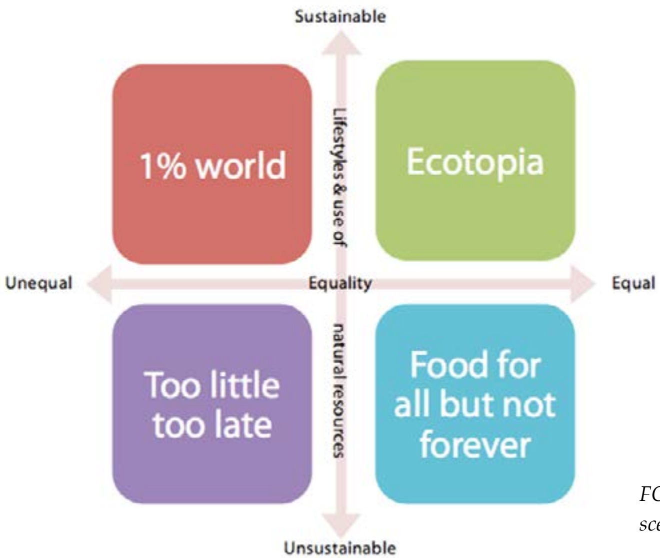
therefore the technology investments add each year 1 billion USD. Of course these effects are very dependent on the oil prices. High fossil energy prices make bio-based substitutes more competitive and therefore lead to higher macro-economic impacts.

The MAGNET model was extended towards the wider bioeconomy by including a biofuels, bioelectricity and biobased chemicals module (Van Meijl et al. 2018a). Philippidis et al. (2018a, 2019) applied bioeconomy assessments to the EU level.




## 5.4 Food security

The food price spike of 2005 put agricultural markets and food security high on the political agenda. For decades low prices were taken for granted and investments in agricultural R&D were low. In the FP7 Foodsecure project coordinated by Wageningen Economic Research, stakeholders developed their own food security scenarios around two key uncertainties (Van Dijk et al., forthcoming). The first one, depicted on the vertical axis, is the often-used sustainability axis to take the environment and the climate into account. The second, and a unique one in long-term modelling, is the equality-inequality axis, which is represented by the horizontal axis. It is about inclusiveness. This is all about income, wealth and health distribution which is under pressure currently. By combining the two key uncertainties, stakeholders created the four Foodsecure scenarios. The purple "Too Little Too Late" scenario represents an unequal and unsustainable world, which

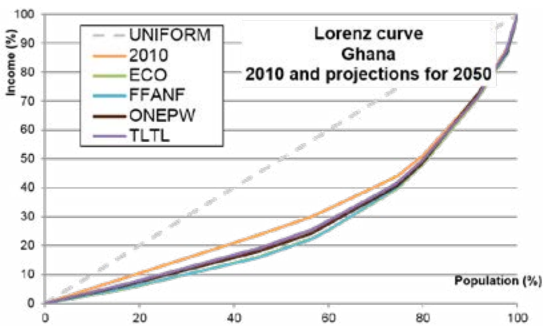



*FOODSECURE scenario storylines*

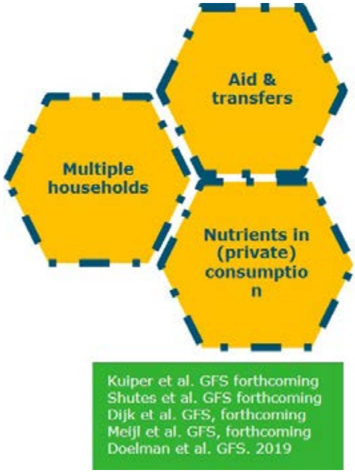
might well represent the current world given the situation regarding the grand societal challenges that I discussed before. At the other extreme is the green Ecotopia scenario, a sustainable and inclusive world which might be our desired world. To flow from the current to the desired worldview is the topic of my lecture. It also answer my first question of today where the beautiful little girl is running to. Why she is smiling! If it stays a dream or becomes a reality is in the hands of mankind.


Foodsecure embraced a broad definition of food security taking food availability, food access (food purchasing power), food utilisation (e.g. nutrition) and food stability into account (Van Meijl et al. forthcoming). Household models were developed to take the income and diet expenditures into account at household level (Shutes et al. forthcomming, Kuiper et al. forthcomming).

*Inequality axis: Future growth not pro-poor, rationale for redistributive policy; 2010 (initial situation), ECO (Ecotopia), FFANF (Food for all but not forever), ONEPW (1% world), TLTL (Too little too late).*



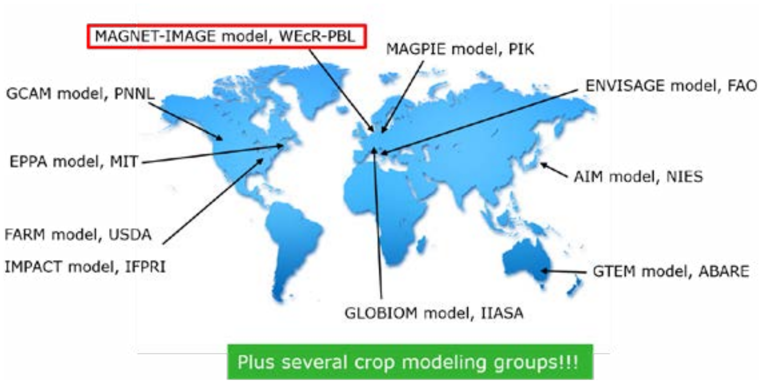
The Lorenz curve, a graphical representation of the distribution of income or of wealth, for Ghana (see graph), shows that the 20% richest people earn half of the total income. The results of the Foodsecure scenario were striking. In all four scenario's the income inequality increased due to the existing macro mechanism. Education and social mobility (rural urban migration) might change this pattern. Quantification of the foodsecure scenario's showed also that food availability increases in all scenario's. However, in general this leads also to more GHG emissions. Only in Ecotopia scenario food availability increases and emissions decrease. Relatively high yields and change in behaviour by reducing waste and changed preferences away from meat contributed to this.




Our modular model was extended with multiple households, aid policies and various nutrients.

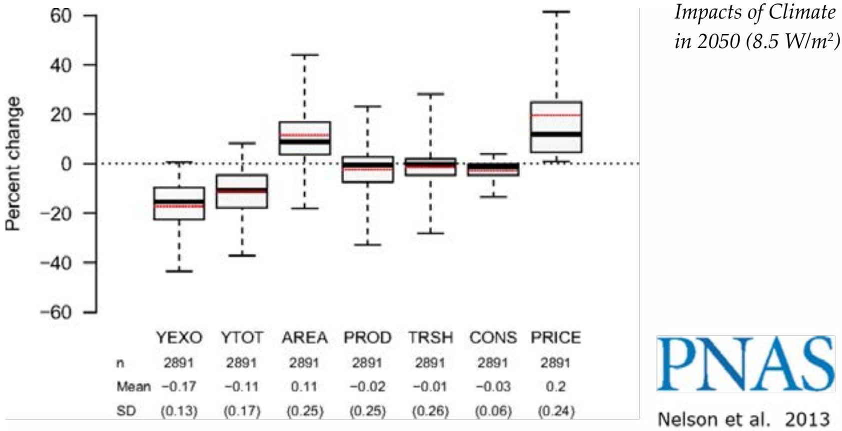
## 5.5 Climate

Plausible estimates of the climate change impacts require combined use of climate, crop, and economic models. Results from previous studies vary substantially due to differences in models, scenarios, and data.



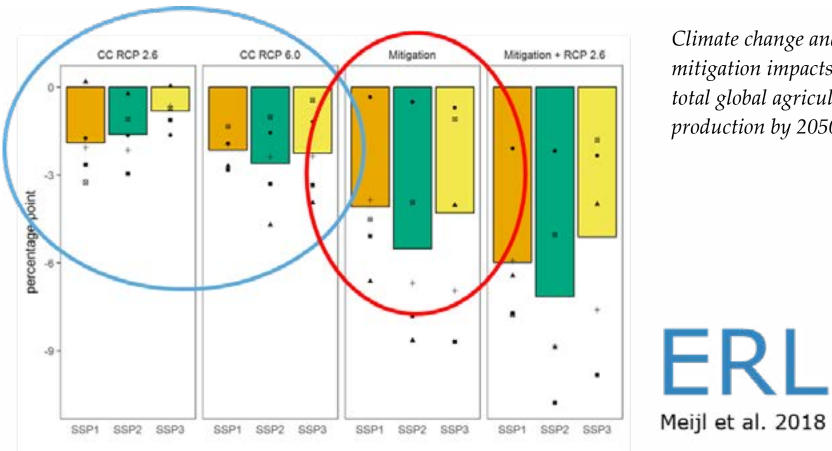

*AgMIP: Ten global economics modelling groups*

In the agricultural modeling comparison project (AgMIP) we tried to understand the differences between 9 world leading economic models based on a harmonised set of scenarios (Nelson et al. 2013, Von Lampe et al. 2014, Stehfest et al. 2019). Partial equilibrium, general equilibrium and integrated assessment models participated.




*Impacts of Climate Change in 2050 (8.5 W/m²)*

AgMIP quantified the impact of a climate change scenario with a radiative forcing 8.5 watts per square meter by 2100 (Nelson et al. 2013, Von Lampe et al. 2014). The exogenous negative yield impact is 17%. Endogenous economic responses reduce yield loss to 11%, increase the area of major crops by 11%, reduce consumption by 3%, and increase agricultural prices by 24%. Agricultural production, cropland area, trade, and prices show the greatest degree of variability in response to climate change, and consumption the lowest.




*Climate change and mitigation impacts on total global agricultural production by 2050*

In an ERL 2018 paper we compared climate change impacts relative to the impact of mitigation measures to stabilize global warming at 2◦C by the end of the century under different Shared Socioeconomic Pathways (Van Meijl et al. 2018b). The impact of only climate change on agricultural production is negative (the two scenarios in the blue circle). A larger negative effect on agricultural production, most pronounced for ruminant meat production, is observed when emission mitigation measures compliant with a 2 ◦C target are put in place (within red circle). In a Nature Climate Change (NCC) 2018 paper, a robust finding is that by 2050, stringent climate mitigation policy would have a greater negative impact on global food security than the impacts of climate change (Hasegawa et al. 2019). These results do not negate the need for mitigation efforts, but rather highlight the need for policy designs that explicitly include complementary measures in order to avoid an increase in hunger and malnutrition (see also Fujimori, et al. 2019). Recently in a 2019 ERL paper we showed that 9% crop productivity growth is needed to mitigate the food security effect and with meat diet changes this would be 7% (Doelman et al. 2019). A second NCC article (Frank et al. 2019) found that agriculture may contribute emission reductions of 0.8–1.4 $GtCO_2e$ per year at just 20 US$ per $tCO_2e$ in 2050. Combined with dietary changes, emission reductions can be increased to 1.8 $GtCO_2e$ per year. At carbon prices compatible with the 1.5 °C target, agriculture could save almost 4 Gt $CO_2e$ per year in 2050, which represents around 8% of current greenhouse gas emissions.


Recently the MAGNET model is extended with a climate change module. Furthermore a Sustainable Development Goal indicator module with a broad coverage (12 out of 17

SDGs covered: SDG 1, 2, 3, 6, 7, 8, 9, 10, 12, 14, 15, 17) has been developed (60+ SDG related indicators, the majority are 'inspired' by the 'targets' which appear in each of the goals, Philippidis et al. 2018b). The MAGNET model with all the modules, I mentioned before, is depicted in the Figure above. MAGNET is flexible regarding country (143 countries, GTAP database) and commodity aggregation (80 sectors, including many MAGNET specific bioeconomy sectors), and time periods (e.g. 2020, 2030, 2050 or 2100). The various modules can be flexible used together as Lego blocks. You can build your own model dedicated to the question at hand. It enables also to possibility to perform sensitivity analyses not only on assumptions and parameters, but also regarding model structure. In general, MAGNET contributes to related (EU) polices (e.g. CAP trade, bioeconomy, fisheries, development), food waste, COP21 climate agreement and SDGs (long run).

## 6 Outlook

Now let's turn to the outlook regarding research and education.

**Research priorities:**

Can we help the little girl? Can we create a transition path to Ecotopia? Can we create a sustainable and inclusive bioeconomy? Can we take planetary security into account by taking care of 'mother earth' our 'common home' and a future to be equally shared with everyone? One of the things, in the area of my professorship, is to upgrade macroeconomic tools, in the area's mentioned below, to support policies and strategic decisions, and to engage with stakeholders.

*Inclusiveness and nutrition*

Distributional issues should become core focus points of the analyses. In addition to income, living standards depend on jobs, the availability of education and health. To achieve this, household level analyses and the functioning of labour markets (education) have to be enhanced. The full flow of micro and macro nutrients is needed to enhance health indicators and enable disease probability functions.

*Sustainability*

Detailed biophysical energy, climate, land and water data and models have to be embedded. A link to water in particular is lacking despite its crucial importance. Market mechanisms at the macro level need to be connected with biophysical information at, for example, the grid level. MAGNET-Grid has to be born!

*Circularity & bio-based*

The transition from a linear towards a circular economy has to be mirrored by a transition in modelling. Principles of the circular economy require the modelling of waste and reuse of materials to create value added. Sound material flow data in physical and monetary are essential. A more detailed representation of new and emerging bioeconomy sectors, such as biobased materials and chemicals is needed and this is the core of the Biomonitor project. Furthermore, the process of technological change has to be endogenized for the circular and bioeconomy.

*A new engine of growth within an inclusive and sustainable bioeconomy framework*
Macro-economic models focus on money flows and ecological variables, resource use and emissions are not taken very well into account. Can we create macro-economics for sustainability that include material and energy flows, emissions and resource use in both biophysical and monetary terms? Furthermore, we have to overhaul or get a new macro-economic engine of growth. Overhaul means decoupling economic growth from material use and emissions based on non-polluting energy and selling non-material services. To decouple economic growth from resource use is needed but it is very difficult in case of growth as current efforts show that the GHG emissions still increase despite all efforts. For many agricultural emissions decoupling is only partly possible. Are there alternatives? Is there another way to Ecotopia? A new engine might mean the challenge of a stable slow or non-growing economy in the long run. This needs change in behaviour of consumers and producers and the governance structure. Can we change lifestyle from consuming more and more individually, driven by novelty and status, towards a different lifestyle in which we care for 'Mother Earth' our 'common home', other people, including future generations and "less is more". From a macro-economic perspective avenues to explore might be opening the black box of consumer preferences, rebalancing work and leisure, shifts from private to public investment, private to public ownership, short-term to long-term investment focus based also on non-economic criteria, and a focus from labour-saving tech change to tech change directed at the grand societal challenges and Sustainable Development Goals.

The worldwide GTAP consortium, and the MAGNET consortium, with JRC and Thuenen Institute, are essential. Cooperation with Plant Sciences and Animal sciences is envisaged to embed better technical yields and crop\animal features, Food and Bio-based Research to cover new food and bio-based technological developments, and Environmental sciences to better cover environmental issues. A coherent systems analysis framework for Wageningen Research to assess the interlinked global challenges in its entire research domain is an ambition that, when realised, would be unique, world leading, and hard to compete with. A coherent Wageningen Research system analyses framework could make a difference in the world by assessing transition pathways to a more inclusive and sustainable society:

To get the girl to Ecotopia!

Deepening of cooperation is also envisaged with the IMAGE integrated assessment model of PBL to cover the whole economy and many earth systems. Within AGMiP we keep on cooperating with other integrated assessment models like the Globiom-Message model of IIASA and the Magpie model of PIK to continuously enhance our models and learn from each other.

### Education

In the last 35 minutes hopefully you have got a good picture of the research programme. Good research builds on good education and vice versa. First, of all I want to contribute to the education programme of the Agricultural Economic and rural Policy (AEP) group. In general, I am concerned about the knowledge of a part of the incoming students in the field of quantitative methods and the limited space in the study programme to this knowledge. Economic modelers, sometimes called five-legged sheep in Dutch, are scarce and hardly educated in Wageningen. However, these are badly needed if WUR wants to match the ambition of a coherent systems analysis framework for Wageningen University and Research to assess the interlinked societal global challenges. Another challenge is that interdisciplinarity is essential to understand global change and the challenge of sustainably feeding a growing planet. Together with Purdue University and Chinese Universities we are setting up an interdisciplinary course to tackle these challenges facing the world's natural resource base. This might be complemented by an advanced Master/PhD course or summer school on applied CGE modelling. CGE models are a laboratory in which to conduct controlled economic experiments and learn how to use economic theory to anticipate and explain results. PhD trajectories will be directed to the research needs identified above.

The research and education agenda is very ambitious and not possible for one person. First, the research agenda is one to one related with the strategy of Wageningen Economic Research, which in turn contributes to various parts of the puzzle (see, e,g, Van Meijl et al. 2017). Furthermore, cooperation is envisaged with colleagues from AEP, other WUR institutes, JRC and TI within the MAGNET consortium, GTAP consortium and the AGMIP project.

## 7 Words of Thanks

I would like to thank the Rector Magnificus Arthur Mol, the executive board of Wageningen University, and the members of the assessment committee for their trust and great support. Our general director Jack van der Vorst, for creating this

opportunity, encouraging me to take this step, and giving me advice on all steps to my professorship.

Professor Justus Wesseler for inspiration and a home from the University side and of course the H2020 Biomonitor project that we set up and coordinate together (www.biomonitor.eu). It is a nice dish for a nice bunch of people. Our business unit manager Olaf Hietbrink for making it possible from the Wageningen Economic Research side.

My promotor Professor Luc Soete inspired me to study general economics and do a PhD. My co-promotor Adriaan van Zon who get me into contact with modelling and my university mates Frank Bunte and Arjen Wolters who even followed me to Wageningen Economic Research. The late Jo Wijnands, who got me to Wageningen Economic Research and always backed me up when I had new ideas. Or do I have to say thanks to Jeroen Hammerstein who became a friend for live. Former director Professor Vinus Zachariasse, who initiated the GTAP cooperation, and always created opportunities for me to grow in my interest field. Professor Gerrit Meester, a demanding client form the Ministry of Agriculture, who always put the right question, and thereby directed the modelling work.

A special thanks to Frank van Tongeren, division head at OECD, who started also in Sept 95 at LEI. We were roommates for 10 years, sometimes called twins, and brought me into contact with CGE modelling and GTAP. The GTAP network brought me into contact with the best modellers of the world, such as Thom Hertel, Dominique van der Mensbrugghe, Peter Dixon and Maureen Rimmer. Important for me were our Dhaka experience, the China Shanghai\Sanya work weeks with Jikun Huang and Jaap Post, and the many GTAP short courses we taught together. Life is unpredictable and sometimes you get a deja vu but then you realise that the situation is totally reversed.

Important was also Martin Banse, Director of TI, who played a key role in the Scenar2020 studies and became known as Martin 'biofuel' Banse as he was key to get the whole biofuel models and papers flying. Except for being on natural ice you were never afraid to get on thin ice. I will never forget that our ERAE paper was written with Gianni on our knee when I was "taking care" of the kids. Funny was also when GTAP founder Thom Hertel had Luca on his knee and kept on talking with a banana in his hand. Luca's eyes were just focused on the banana while Thom kept talking. Suddenly when Thom made one more move. Luca came forward and put the whole banana in his month, to the great surprise of Thom.


Of course the MAGNET team with my closest partner Andrzej Tabeau and co-author on most of my publications (82 together, incredible) which were not possible without your enormous effort and push. Our talents are very complementary and together we are a great team. Special thanks to Marijke Kuiper, the creative and always inspiring MAGNET lady, who as an architect designed the MAGNET philosophy, based on LEITAP. Geert Woltjer, the key modeller in the LEITAP days after Frank left, made things work and implemented a lot of the MAGNET Philosophy. Luckily Heleen Bartelings could take over this central role when Geert left. Of course also the rest of the team! It is an honour to work with Monica, Zuzana, Marie, Jason, David, Lindsay, Diti, Saeed, Michiel, Myrna, John, Ewa, John, Eugene, and all others.

MAGNET is an international consortium with JRC Seville of the European Commission and TI. A special word of thanks to Robert MBarack and George Philippidis of JRC as the key driving forces to make MAGNET perform better in the CAP and bio-economy policy landscape by providing direction and investments. Very important was the cooperation with PBL, who are extremely good in assessing the agenda for the future and broadening my narrow macro-economic horizon. Of course Bas Eickhout, was key for the initial land link between the systems. Luckily when Bas moved to the European parliament, Elke Stehfest, a very talented researcher, took over. Elke Iam so happy you are back. A great thanks to the IMAGE team leader and KNAW fellow Detlef van Vuuren, and, Tom Kram, Jonathan Doelman and Willem Jan van Zeits.

A special word of thanks to Thom Achterbosch, who initiated the first huge H2020 project Foodsecure together with me. Thom's creative mind just never stops. Also thanks to my trade and daily bike companion Siemen van Berkum. Harriette Bos, Peter Besseling, Andre Faay, Luuk van de Wielen and Patricia Osseweijer who inspired me towards the field of the biobased economy.


The very successful CV de Dorstlessers (see picture), with all my friends from my youth, provided me with some of my most important lessons in life. Creativity and teamwork are key. Use all the talents in a group, put the ambition level high, do not imitate but be original. These basic principles are still my guiding principles.

On my spiritual path, all members of Pro Deo, especially the Vos brothers and my nephew Jos. Peter Nowicki, who also was the project leader of the Scenar2020 studies, brought me into contact with Chemin Neuf. All members and especially Ruth, Stephany, Jean Paul, Emmanuel and our 3 months sabbatical in Zaragoza provide daily inspiration.

*Broers en zussen, neefjes en nichtjes, ooms en tantes, wie kon ooit gedacht hebben dat een zoon van Paul van Meijl en Mien Belien van het kleine dorpje Gastel professor zou worden. Ik verloor mijn vader veel te vroeg toen ik 14 jaar oud was maar hij had mij het voorbeeld gegeven om in het openbaar op te treden, je in te zetten voor de gemeenschap, hard te werken en de rijkdom van internationale relaties te ervaren. Mijn moeder bracht me de liefde voor de natuur\tuin en de minder bedeelde medemens mee. Natuur en medemens, zijn nog steeds leidend en de twee kern woorden in de titel van mijn oratie.*

Brothers and sisters, niece and nephews, aunts and uncles, who could have expected that a son from Paul van Meijl and Mien Belien from the little village of Gastel would become professor. I lost my father much too early when I was 14 years old but he taught me to engage in public activities, work hard and experience the richness of international relations. My mother brought me the love for nature and less fortunate people. These are the two key words in the title of this lecture.

Only one can be the most important person in your life and for me this is Ria, who always gives me her love and support and went with me on my crazy adventure trips all over the world and gives me the freedom to develop myself and follow my dreams. Together we got our sons Gianni and Luca on which I am proud beyond words.

*Rector Magnificus, ik heb gezegd.*

## References


Alcamo, J., Leemans, R., Kreileman, G.J.J., (1998), Global Change Scenarios of the 21st Century. Results from the IMAGE 2.1 Model. Pergamon and Elseviers Science, London.

Banse, M., J. Helming, P. Nowicki and H. van Meijl, (2008a), Future of European Agriculture under Different Policy Options. Agrarwirtschaft, 57, pp. 156-164.

Banse, M., H. van Meijl, A. Tabeau and G. Woltjer, (2008b), Will EU Biofuel Policies affect Global Agricultural Markets? European Review of Agricultural Economics, 35: 117-141.

Banse, M., H. van Meijl, A. Tabeau, G. Woltjer, F. Hellmann, P. Verburg, (2011), Impact of EU biofuel policies on world agricultural production and land use, Biomass and Bioenergy, 35, pp. 2385-2390.

Banse, M., F. Junker, A. Gerdien Prins, E. Stehfest, A. Tabeau, G. Woltjer, H. van Meijl, (2014), Global impact of multinational biofuel mandates on land use, feedstock prices, international trade and land-use greenhouse gas emissions, Landbauforschung Volkenrode, 06/2014; 64(2):59-71.

Coase, R. (1960), The problem of social cost, Journal of Law and Economics, Vol. 3, pp. 1-44.

Covey, S.R. (1989), The 7 habits of highly effective people, The business library.

Doelman J., E Stehfest, A, Tabeau, H, van Meijl, (2019), Making the Paris agreement climate targets consistent with Food Security objectives, Global Food Security, Volume 23, December 2019, Pages 93-103.

European Commission (2012), Innovating for Sustainable Growth: A Bioeconomy for Europe, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions; European Commission, DG Research and Innovation: Brussels, Belgium, 2012

European Commission (2015), European Environment-State and Outlook report (SOER). http://www.eea.europa.eu/soer (2015).

Eickhout, B., H. van Meijl, T. van Rheenen and A. Tabeau, (2007), Economic and ecological consequences of four European land-use scenarios, Land Use Policy, 24, 562–575.

Francois, J., van Meijl, H. and van Tongeren, F. (2005), 'Trade liberalisation in the DOHA Development Round' Economic Policy , pp. 351-391.

Frank., S., P. Havlík, E. Stehfest, H. van Meijl, P. Witzke, I. Perez-Dominguez, J. C. Doelman, T. Fellmann, J. F.L. Koopman, A. Tabeau, H. Valin, (2019), Agriculture mitigation wedges for a 1.5 degree world: a multi-model assessment, Nature Climate Change, volume 9, pages 66–72 (IF 19.3)

Fujimori, S., T. Hasegawa, T., K. Takahashi, K., O. Fricko, O.S. Frank, S.P. Havlik P., V. Krey, V.R. Keywan, R.D. van Vuuren, D.J. Doelman, J.A. Popp, A. H. van Meijl, H. F. Humpenöder, F. B. L.Bodirsky, B.L.J. Després, J.A. Schmitz, A.L. Drouet, L.J. Emmerling, J. andV. Bosetti, V., (2019), A multi-model assessment of food security implications of climate change mitigation, Nature Sustainability, 2, pages 386–396.

Hasegawa, T., S. Fujimori, P. Havlik, H. Valin, B. Bodirsky, J. Doelman, T. Fellmann, P. Kyle, J. Levin-Koopman, H. Lotze-Campen, D. Mason-D'Croz, Y. Ochi, I. Perez-Dominguez, E. Stehfest, T. B. Sulser, A. Tabeau, K. Takahashi, J. Takakura, H. van Meijl, W. van Zeist, K. D. Wiebe, P. Witzke, (2018), Risk of increased food insecurity under stringent global climate change mitigation policy, Nature Climate Change, volume 8, pages 699–703.

Hertel, T.W. (ed.), (1997), Global Trade Analysis: Modeling and Applications, Cambridge University Press.

Hochman, G., D. Rajagopal and D. Zilberman (2010), "The Effect of Biofuels on Crude Oil Markets." AgBioForum 13(2).

Huang, J., R. Hu, H. van Meijl, and F. van Tongeren (2004), Biotechnology Boosts to Crop Productivity in China: trade and welfare implications, Journal of Development Economics , vol 75, pp. 27-54.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), (2019), Global Assessment of the State of Biodiversity and Ecosystem Services.

ILO & OECD, (2015), The Labour Share in G20 Economies, International Labour Organization Organisation for Economic Co-operation and Development. Report prepared for the G20 Employment Working Group Antalya, Turkey, 26-27 February 2015.

IMF, (2015), IMF Survey : Counting the Cost of Energy Subsidies; See http://www.imf.org/external/pubs/ft/survey/so/2015/NEW070215A.htm

Joint Research Centrum (JRC), (2015), Energy use in the EU food sector: State of play and opportunities for improvement, JRC Science and Policy Report, European Union, 2015.

Kaldor, N., 1957, A model of economic growth, The Economic Journal, vol. 67, pp. 591-624.

Kaldor, N., 1961, Capital Accumulation and Economic Growth. In: F. Lutz, ed., Theory of Capital, London: MacMillan.

Klijn, J.A., L.A.E. Vullings, M.v.d. Berg, H. van Meijl, R. van Lammeren, T. van Rheenen, A. Veldkamp, P.H. Verburg, H. Westhoek and B. Eickhout, (2005), The EURURALIS study: Technical document, Alterra-rapport 1196, Alterra, Wageningen, 2005.

Kuiper, M., L. Shutes, H. van Meijl, A. Tabeau, D. Oudendag, (forthcoming), Labor supply assumptions - the missing link in food security projections, Global Food Security.

Kuznets, S., 1957, Quantitative aspects of economic growth of nations: II, Economic Development and Cultural Change, Supplement to vol. 5, 3-111.

Meadows, D. H; Meadows, D. L; Randers, J.; Behrens, William W (1972). The Limits to Growth; A Report for the Club of Rome's Project on the Predicament of Mankind. New York: Universe Books. ISBN 0876631650. Retrieved 26 November 2017.

Nelson, G., H. Ahammad, D. Deryng, J. Elliott, S. Fujimori, P. Havlik, E. Heyhoe, P. Kyle, M. von Lampe, H. Lotze-Campen, D. Mason d'Croz, H. van Meijl, D. van der Mensbrugghe, C. Müller, R. Robertson, R. D. Sands, E. Schmid, C. Schmitz, A. Tabeau, H. Valin, D. Willenbockel (2013), Assessing uncertainty along the climate-crop-economy modeling chain, Proceedings of the National Academy of Sciences U.S.A. 111(9): 3274-3279.

Nowicki, P., H. van Meijl, A. Knierim, M. Banse, J. Helming, O. Margraf, B. Matzdorf. R. Mnatsakanian, M. Reutter, I. Terluin, K. Overmars, D. Verhoog, C. Weeger, H. Westhoek (2006), Scenar 2020 - Scenario study on agriculture and the rural world. Contract No. 30 - CE - 0040087/00-08. European Commission, Directorate-General Agriculture and Rural Development, Brussels.

Nowicki, P., V. Goba, A. Knierim, H. van Meijl, M. Banse, B. Delbaere, J. Helming, P. Hunke, K. Jansson, T. Jansson, L. Jones-Walters, V. Mikos, C. Sattler, N. Schlaefke, I. Terluin and D. Verhoog (2009), Scenar 2020-II – Update of Analysis of Prospects in the Scenar 2020 Study – Contract No. 30–CE-0200286/00-21. European Commission, Directorate-General Agriculture and Rural Development, Brussels.

OECD, (2013), Crisis Squeezes Income and puts Pressure on Inequality and Poverty, OECD Publishing, Paris.

OECD, (2014a), Jobs, Wages and Inequality, OECD Publishing, Paris.

OECD, (2014), Climate Change, Water and Agriculture: Towards Resilient Systems, OECD Studies on Water, OECD Publishing, Paris.

OECD, (2017), Inclusive growth, http://www.oecd.org/inclusive-growth/

Philippidis, G., H. Bartelings, J. Helming, R. M'barek, E. Smeets, H. van Meijl, (2018a), The Good, the Bad and the Uncertain: Bioenergy use in the European Union, Energies 2018, 11(10), 2703; https://doi.org/10.3390/en11102703 ( IF 2.7).

Philippidis, G., Bartelings, H., Helming, J., M'Barek, R., Ronzon, T., Smeets, E., van Meijl, H., Shutes, L., (2018), The MAGNET model framework for assessing policy coherence and SDGs - Application to the bioeconomy. EUR 29188 EN, Publications Office of the European Union, 2018b, Luxembourg, 2018,ISBN 978-92-79-81792-2, doi: 10.2760/560977, JRC111508.

Philippidis, G., H. Bartelings, J. Helming, R. M'Barek, E. Smeets, H. van Meijl (2019). Levelling the playing field for EU biomass usage. Economic Systems Research, p. 1-20.
Rienks, W.A., A. Balkema, M. Banse, B. Eickhout, I. Geijzendorffer, H. van Meijl, H. van den Heiligenberg, K. Overmars, A.G. Prins, I. Staritsky, A. Tabeau, P. Verburg, P. Verweij, W. Vullings, H. Westhoek, G. Woltjer, (2008), Eururalis: an integrated impact assessment framework to support policy discussion about the future of Europe's rural areas.
Romer, P., (1986), Increasing returns and long run growth, Journal of Political Economy, Vol. 94, no. 5, pp. 1002-1037.
Ronzon, T. et al., (2017), A systematic approach to understanding and quantifying the EU's bioeconomy. Bio-based and Applied Economics, v. 6, n. 1, p. 1-17, Jul. 2017.
Shutes, L., M. Kuiper, D. Oudendag, H. van Meijl, A. Tabeau, (forthcoming) Factor representation – a missing link in household food security projections, Global Food Security.
Smeets, E., A. Tabeau, S. van Berkum, H. van Meijl, G. Woltjer, J. Moorad, (2014), The impact of the rebound effect of the use of first generation biofuels in the EU on greenhouse gas emissions, Renewable and Sustainable Energy Reviews 10/2014; 38:393–403.
Smeets- Kristkova, Z., M. van Dijk, H. van Meijl, (2016), Projections of long-term food security with R&D driven technical change – a CGE analysis, NJAS-Wageningen Journal of Life Sciences, 77, 39-51.
Smeets- Kristkova, Z., M. van Dijk, K. Gardebroek, H. van Meijl, (2017a), The impact of R&D on factor-augmenting technical change – an empirical assessment at the sector level, Economic Systems Research, Vol. 29 , Iss. 3, Pages 385-417.
Smeets- Kristkova, Z., M. van Dijk, H. van Meijl (2017b), Assessing the impact of agricultural R&D investments on long-term projections of food security, Frontiers of Economics and Globalization 17 . - p. 1 - 17.
Solow, R., (1986), On the Intergenerational Allocation of Natural Resources, Scandinavian Journal of Economics, 88, issue 1, p. 141-49.
Stehfest, E., Van Vuuren, D. P., Kram, T. & Bouwman , A. F. (eds.), (2014), IMAGE 3.0: PBL Netherlands Environmental Assessment Agency.
Stehfest, E, W van Zeist, H. Valin, P. Havlik, A. Popp, P. Kyle, A. Tabeau, D. Mason-D'Croz, T. Hasegawa, B. L. Bodirsky, K. Calvin, J. Doelman, S. Fujimorb, F. Humpenöder, H. Lotze-Campei, H. van Meijl, K. Wiebe, (2019), Key determinants of global land-use projections, Nature Communication, 10, Article number: 2166.
Stockholm Statement, (2016), Towards a Consensus on the Principles of Policymaking for the Contemporary World, 15 November 2016.
UN, (2015), Transforming our world: the 2030 Agenda for Sustainable Development,

2015.
UNFCCC: United Nations Framework Convention on Climate Change (2015). Adoption of the Paris Agreement. Proposal by the President (1/CP21) [cited 2016 02, Feb.] Available from: http://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf. 2015.

Van Dijk, M., M. Gramberger, D. Laborde, M. Mandryk, L. Shutes, E. Stehfest, H. Valin, K. Zelllmer, (forthcoming), Global food security scenarios up to 2050: Development process, storylines and quantification of drivers, Global Food Security.

Van Leeuwen, M., H. van Meijl and E. Smeets, (2013), Overview of the Systems Analysis Framework for the EU Bioeconomy. Report prepared for the Systems Analysis Tools Framework for the EU Biobased Economy Strategy project (SAT-BBE). SAT-BBE project team; LEI part of Wageningen UR, the Hague, the Netherlands.

Van Meijl, H., (1995), "Endogenous Technological Change: The Influence of Information Technology, Theoretical Considerations and Empirical Results", PhD Thesis, Maastricht.

Van Meijl, H., F.W. van Tongeren, (1998), Trade, technology spillovers and food production in China, Weltwirtschaftliches Archiv, vol. 134, no. 3, pp. 423-449.

Van Meijl, H., F.W. van Tongeren, (1999), Endogenous international technology spillovers and biased technical change in agriculture, Economic Systems Research, Vol. 11, No. 1, pp 31-48.

Van Meijl, H., van and F.W. van Tongeren, (2002), The Agenda 2000 CAP reform, world prices and GATT-WTO export constraints, European Review of Agricultural Economics, Vol 29 (4) (2002) pp. 445-470.

Van Meijl, H., and F. van Tongeren (2004), International diffusion of gains from biotechnology and the European Union's Common Agricultural Policy, Agricultural Economics, 31, pp. 307-316.

Van Meijl, H., T. van Rheenen, A. Tabeau and B. Eickhout (2006), The impact of different policy environments on land use in Europe, Agriculture, Ecosystems and Environment, Vol. 114, pp. 21-38.

Van Meijl, H., E. Smeets, M. van Dijk, J. Powell, (2012), Macro-economic Impact Study for Bio-based Malaysia, LEI report 2012-042.

Van Meijl, H., E. Smeets and D. Zilberman, (2015), Bioenergy Economics and policies, in Glaucia Mendes Souza, Reynaldo Victoria, Carlos A. Joly and Luciano M. Verdade, Bioenergy & Sustainability: bridging the gaps, Scientific Committee on Problems of the Environment (SCOPE), Vol. 72, p. 779. Paris, ISBN 978-2-9545557-0-6.

Van Meijl, H., I. Tsiropoulos, H. Bartelings, M. van den Broek, R. Hoefnagels, M. Van Leeuwen, E. Smeets, A. Tabeau and A. Faaij, (2016), Macroeconomic outlook

of sustainable energy and biorenewables innovations (MEV II), Wageningen, LEI report 2016-001, 168 pp.
Van Meijl, H., R. Ruben and S. Reinhard, (2017), Towards an inclusive and sustainable economy, Wageningen University and Research, Wageningen January 2017.
Van Meijl, H., Y. Tsiropoulos, H. Barteling, R. Hoefnagels, E. Smeets, A. Tabeau, A Faaij, (2018a), On the macro-economic impact of bioenergy and biochemicals – Introducing advanced bioeconomy sectors into an economic modelling framework with a case study for the Netherlands, Biomass and Bioenergy, 108, p. 381 - 397.
Van Meijl, H., P. Havlik, H. Lotze-Campen, E. Stehfest, P. Witzke, I. Pérez Domínguez, B. Bodirsky, M. van Dijk, J. Doelman, T. Fellmann, F. Humpenoeder, J. Levin-Koopman, C. Mueller, A. Popp, A. Tabeau, H. Valin, W van Zeist, (2018b), Comparing impacts of climate change and mitigation on global agriculture by 2050, Environmental Research Letters. 13 064021, https://doi.org/10.1088/1748-9326/aabdc4.
Van Meijl, H. L. Shutes, H. Valin, E. Stehfest, M. van Dijk, M, Kuiper, A, Tabeau, W. van Zeist, T. Hasegawa and P. Havlik,(forthcoming) Modelling alternative futures of global food security: Insights from FOODSECURE, Global Food Security.
Van Tongeren, F.W., H. van Meijl and Y. Surry, (2001), Global models of trade in agriculture and related environmental modelling: a review and assessment, Agricultural economics, Vol 1493, p.1-24.
von Lampe, M., Willenbockel, D., Ahammad, H., Blanc, E., Cai, Y., Calvin, K., Fujimori, S., Hasegawa, T., Havlik, P., Heyhoe, E., Kyle, P., Lotze-Campen, H., Mason d'Croz, D., Nelson, G. C., Sands, R. D., Schmitz, C., Tabeau, A., Valin, H., van der Mensbrugghe, D. and van Meijl, H. (2014), Why do global long-term scenarios for agriculture differ? An overview of the AgMIP Global Economic Model Intercomparison. Agricultural Economics, 45: 3–20.
Verburg, P.H., Eickhout, B., van Meijl, H. (2008), A multi-scale, multi-model approach for analyzing the future dynamics of European land use. Annals of Regional Science, 42(1): 57-77.
Wicke, Verweij, van Meijl, van Vuuren and Faaij (2012), Indirect land use change: review of existing models and strategies for mitigation, Biofuels, 3(1), 87-100.
Woltjer G, Kuiper M, A. Kavallari, H. van Meijl, J. Powell, M. Rutten, L. Shutes and A. Tabeau, (2014), The MAGNET model - Module description. LEI Report 14-057. The Hague: LEI - part of Wageningen UR (University & Research centre).
World Commission on Environment and Development (WECD) (1987), Our Common Future. Oxford: Oxford University Press. p. 27. ISBN 019282080X.

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*'A major societal challenge of the 21st century is how to feed a growing world population in a sustainable and inclusive manner which strengthens resilience to climate change and incorporates concerns for planetary security. In this lecture the common thread is that this professorship contributes to an inclusive and sustainable bioeconomy by designing and implementing a system analysis framework, from a macro-economic perspective, that supports coherent policies that address this major societal challenge.'*

ISBN 978-94-6395-086-2