Modelling the regional economic impacts of biofuels

Lessons from non-marine derived biofuels for marine algae production in Northern Ireland, the Border region of Ireland and Western Scotland

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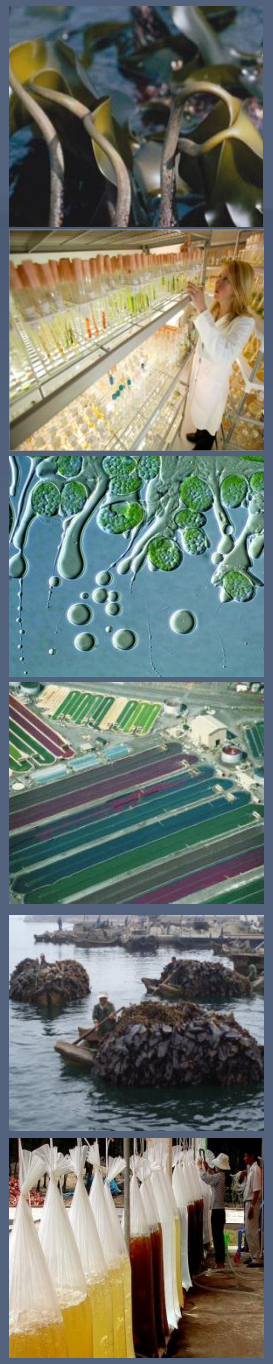

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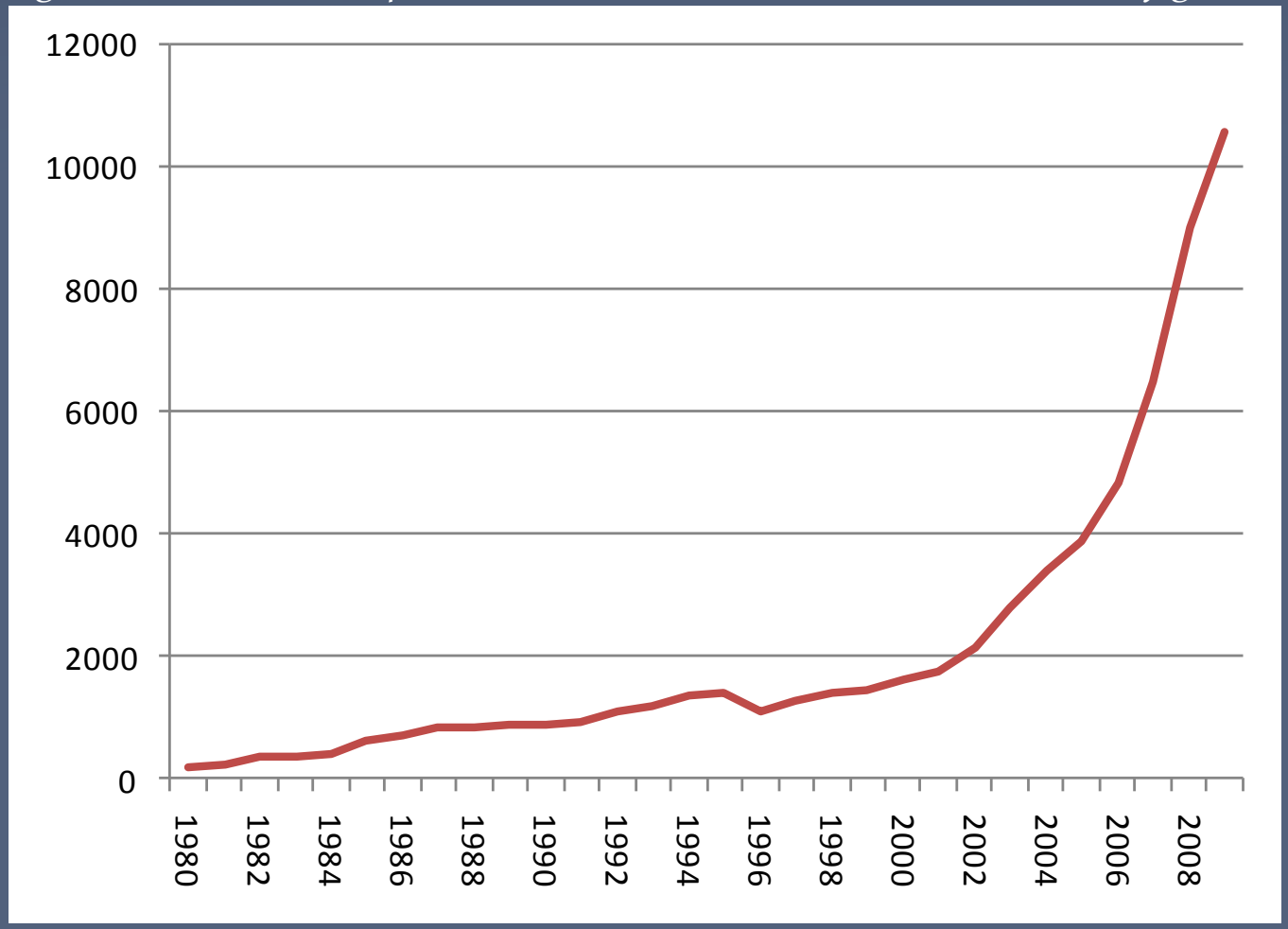
Recent increase in biofuels production (1)

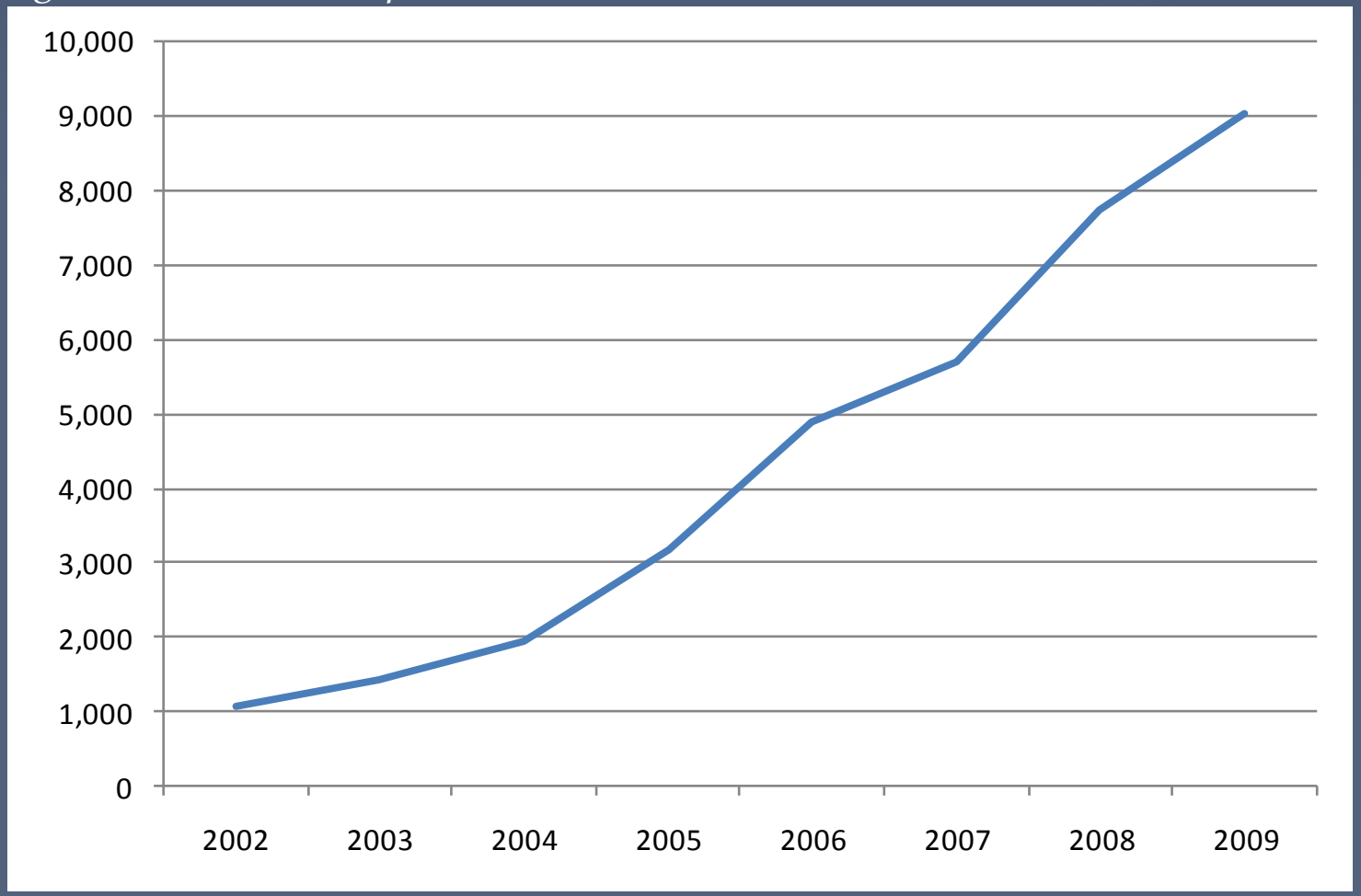
Figure 1: Fuel ethanol production in the US, 1980-2009 (millions of gallons p.a.)



Source: Renewable Fuels Association (2010)

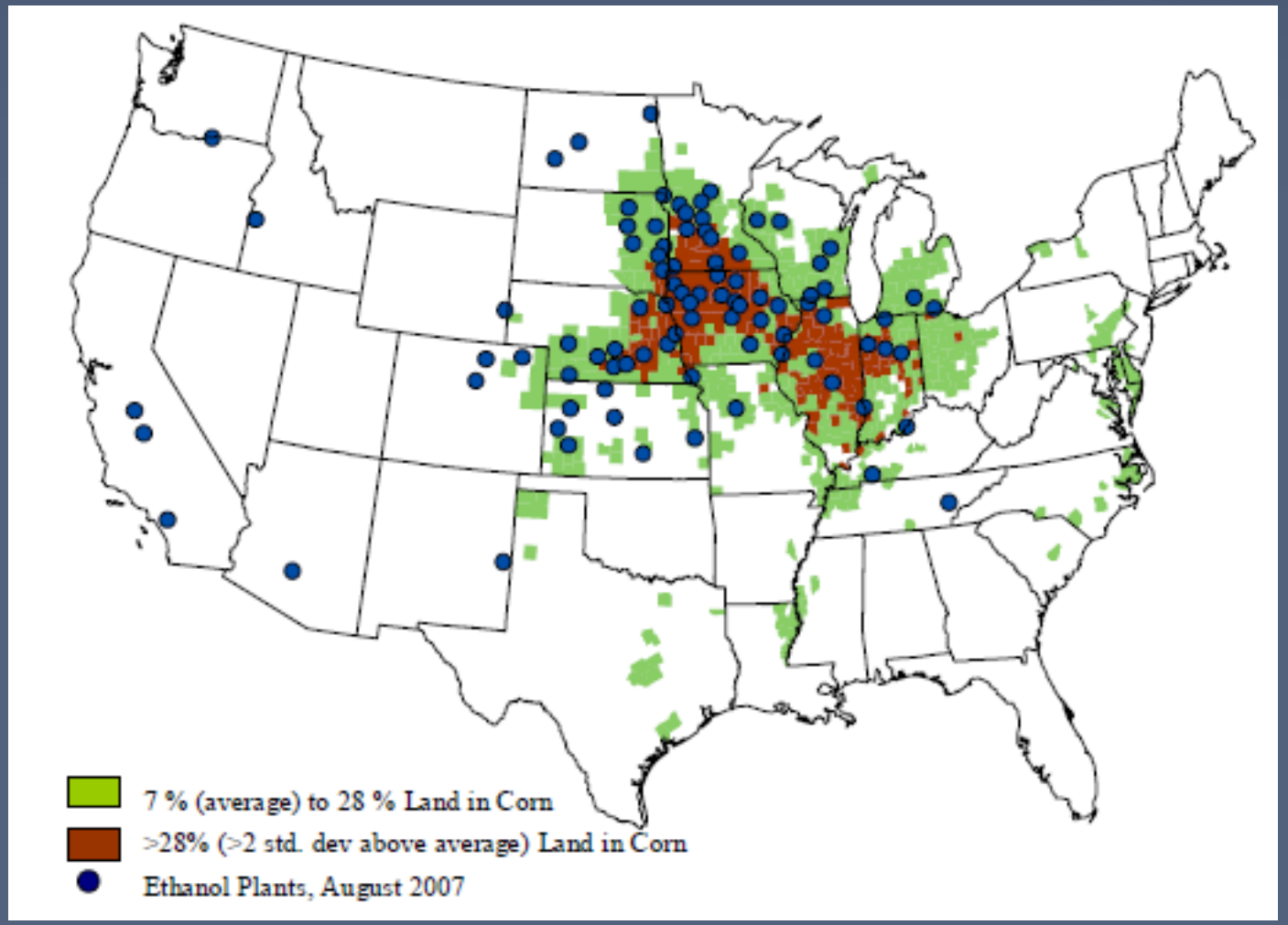
Recent increase in biofuels production (2)

Figure 2: EU biodiesel production 2002 to 2009, 000 tonnes



Source: European Biodiesel Board (2010)

Regional dimension



Why biofuels?

- Lower greenhouse gas emissions from transport
- Improve energy security by lowering imports/increasing diversity of fuel supply
- Improve rural development by supporting farm crop income
- “Triple-dividend” not apparent from evidence to date
  - Land use changes damaging greenhouse gas savings
  - Diverting food materials to energy feedstocks, pushing up food prices

Biofuels in the UK

- UK biodiesel production in 2009, 1.5% of EU total
- Road Transport Fuel Obligation (RTFO) requires suppliers to produce certificates for annually increasing share of fuels supplied
  - 3.25% in 2009/10
- Assessment of first year of RTFO (2008/9) shows
  - 2.7% of UK fuels from biofuels
  - 5% of biofuels produced in the UK
    - 4% of UK oilseed rape crop, 8% of UK sugar beet crop
  - Imported biodiesel from the US, Germany, and bioethanol from Brazil

Outline of presentation

1. Fixed-price regional models and applications to biofuels
    - Input-Output and Social Accounting Matrix approaches used
2. Computable General Equilibrium (CGE) models and applications to biofuels
3. Discussion of modelling approaches
4. Future research plans

1. Single-region IO modelling

Exogenous demands "drive" regional output through Leontief inverse

$$X = (I - A)^{-1} Y \quad \Rightarrow \quad \Delta X = (I - A)^{-1} \Delta Y$$

where $a_{ij} = x_{ij} / X_j$

Sectoral "Multipliers" show impact of £unit of final demand for sectors output on region

Where facility is not already represented in the economy, need to create a new sector, which sees the new (exogenous) final demand

Research then focuses on linkages between biofuels industry and regional economy

- Technology choice may drive regional inputs, and so, regional impacts.

Introducing a new sector in IO

Before

	Agriculture	Oil and gas extraction	Refined petrol	Non-service	Services	BIOFUELS	Total intermediate demand	Final demand	Gross output
Agriculture	271	271	1	1	0	631	199	$a_{16}X_6$	199	1101+a16X6	1,597	1,597	2,699
Oil and gas extraction	1	1	76	76	820	820	504	$a_{26}X_6$	30	1431+a26X6	1,251	1,251	2,683
Refined petrol	32	32	14	14	57	257	278	$a_{36}X_6$	428	808+a36X6	1,200	1,200	2,008
Non-service	239	239	526	526	62	9162	9,162	$a_{46}X_6$	3,534	13543+a46X6	35,962	35,962	49,505
Services	398	398	753	753	98	4893	4,852	$a_{56}X_6$	8,244	34346+a56X6	79,715	79,715	114,061
BIOFUELS								$a_{66}X_6$		$a_{66}X_6$		f_6	X_6
Total intermediate purchases	941		1369		1038	15447	32435			51230	119,726		
Imports to RUK		519		463		642	8,882		0,745	21,250	15,775		37,025
Imports to ROW	519	234	463	165	642	8882	4,701	$a_{ruk}X_6$	4,977	10,125+a	8,575	775	18,701
Net taxes on product and productio	-234	65	165	11	49	4784	842	$a_{row}X_6$	3,638	4,511+a	8,142	575	12,653
Compensation of employees	-65	399	11	614	84	1678	11,967	a_tX_6	0,088	53,244+a	-	142	53,244
Gross operating surplus	399	671	614	62	176	11967	7,668	$a_{coe}X_6$	2,178	30,596+a	-	-	30,596
Total primary inputs	671	1,758	62	1,314	18	7668	34,058	$a_{ova}X_6$	1,626	119,726	32,492	-	152,219
Total primary inputs	1758		1314		970	34058	81626			119726	32,492		
Total gross inputs		2,699		2,683		2,008	49,505		4,061	170,957	152,219		323,175
Total gross inputs	2699		2683		2008	49505	114061	X_6		170957	152,219		

Assumptions of demand-driven IO modelling

- Fixed coefficient production technology with constant returns to scale
- Fixed coefficients in consumption (when consumption endogenous)
- No supply constraints (for endogenous sectors)

Necessary "ad-hoc" adjustments?

- "World is not as simple as demand-driven, fixed-proportions inputs output model" Low and Isserman (2009)

Set = zero

$X_2^* = X_2$

	Agriculture	Oil and gas extraction	Refined petrol	Non-service s	Services	BIOFUELS	Total intermediate demand	Final demand	Gross outpu
Agriculture	271	1	0	631	199	$a_{16}X_6$	1101+a16X6	1,597	X_1^*
Oil and gas extraction	1	76	820	504	30	$a_{26}X_6$	1431+a26X6	1,251	X_2^*
Refined petrol	32	14	57	276	428	$a_{36}X_6$	808+a36X6	1,200	X_3^*
Non-service	239	526	62	9182	3534	$a_{46}X_6$	13543+a46X6	35,962	X_4^*
Services	398	753	98	4853	28244	$a_{56}X_6$	34346+a56X6	79,715	X_5^*
BIOFUELS						$a_{66}X_6$	$a_{66}X_6$	f_6	X_6
Total intermediate purchases	941	1369	1038	15447	32435		51230	119,726	
Imports to RUK	519	463	642	8882	10745	$a_{ruk}X_6$	21250	15,775	
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Compensation of employees	399	614	176	11967	40088	$a_{coe}X_6$	53244	-	
Gross operating surplus	671	62	18	7666	22178	$a_{ova}X_6$	30596	-	
Total primary inputs	1758	1314	970	34058	81626		119726	32,492	
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To prevent new "Biofuels" sector increasing output of Oil and Gas Extraction sector…

Kulisic *et al* (2007))

- or not change at all from existing output (e.g. Swenson (2006) or Low and Isserman (2009)

Alternative approaches?

- Steinback (2004) shows how sectoral output can be used as a constraint, with final demand (e.g. exports) adjusting

$$\begin{bmatrix} (1-a_{11}) & -a_{21} & 0 \\ -a_{21} & (1-a_{22}) & 0 \\ -a_{31} & -a_{21} & -1 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ F_3 \end{bmatrix} = \begin{bmatrix} \hat{F}_1 + a_{13}\hat{X}_3 \\ \hat{F}_2 + a_{23}\hat{X}_3 \\ (1-a_{13})\hat{X}_3 \end{bmatrix}$$

- *"many analysts believe that the assumption of excess capacity an unused resources is unrealistic when applied to the agricultural sector of many regions" (Thorbecke, 1998)*
  - SAM multipliers can be "constrained" to sectoral limits– which need not be current output

- Fixed price multipliers "represent the upper bound estimate"
  - true value (where one sector is supply constrained at any point) lies between zero and fixed price multiplier

2. Computable General Equilibrium modelling

- Empirical economic models, of which IO is a special case
- Set of equations describe production, consumption and trade
- Benchmark database for regional economy is a Social Accounting Matrix describing production, consumption and income flows in the target economy for the base year in question
- Can be used for comparative static analysis or dynamic
- Solve for equilibrium for a given set of prices/quantities

Why might CGE models be useful?

- No fixed coefficient production assumptions and so input substitution possible
    - Inputs used respond to relative price differentials
- Can incorporate supply constraints, for example, in labour and capital market, where demand could bid up prices and wages
    - Labour and capital factors of supply can adjustment over time in response to price differences
- Other factors of production can be consistently incorporated, e.g. suitable land.

Important because…

- Land can be modelled in a consistent way
  - e.g. homogenous land, but fixed in supply (e.g. Dixon *et al* (2007), Kretschmer *et al* (2008)) or modelled with consistent elasticity of transformation (CET) where land can be transformed to alternative uses at a cost…
- Land use changes can be incorporated
  - "direct and indirect land use change is the most significant factor for the overall GHG balance and thus the environmental impact of biofuels"
- By-products and biofuel trade can be systematically modelled
- *"World is not as simple as demand-driven, fixed-proportions inputs output model", Low and Isserman (2009)*

Biofuels treatment in CGE modelling to date (Kretschmer and Peterson, 2010)

- "Implicit approach"
  - Assume that cost reduction for technology is made and that alternative is displaced, e.g. oil inputs are displaced by 25% biofuels (Dixon et al, 2007)
  - But too simplistic to assume cost developments are made?

- "Latent technologies"
  - Technologies not available in the base year, but which become "active" at specific prices
  - Dynamics and substitutability are imposed, but are they known with certainty for developing technologies?

- "Disaggregating the SAM"
  - Identify the sectors for biofuels and model these directly
  - "most promising future approach… which should become more feasible as more extensive and reliable data on the growing biofuels sector become available" (K+P, 2010).

3. Assessment of alternative approaches

IO/SAM	CGE
Fixed coefficients	Hierarchical production functions allowing substitution between inputs
No price effects	Full response price effects
Quantities adjust	Prices and quantities adjust
No supply constraints (demand driven)	Demand and supply interact

Adapted from West (1995), "Comparison of Input-Output, Input-Output Econometric and Computable General Equilibrium Impact models at the regional level", Economic Systems Research, Vol. 7, No. 2, p. 209-227

Some conclusions

- Demand for regional impacts of biofuels to be estimated
- Modelling can be vital and shed light on nature of economy-environmental trade offs
- Models must be appropriate for purpose
- Suggests that (unconstrained) IO models have limited scope to cover the specific issues important for the regional economic (and environmental, including land use) impact of biofuels production.

Are conclusions valid for biofuels from marine algae?

	Ethanol/biodiesel	Marine algae
Factors of production	Corn/Sugar cane/Sugar beet/Oilseed rape/ Vegetable oil + other inputs (e.g. gas, water, etc)	Algae, carbon dioxide, water,
Constraint on growth	Availability of appropriate land	Suitable growing conditions (ocean or lab)
Competition for factors of production	Food stocks/other land uses	Other ocean users
% of US cropland required to produce 50% of US transport fuel needs from biodiesel (Yusuf Chisti, 2007)	Corn = 846% Soybean = 326%	Microalgae = 1.1%-2.5%
Cost of biodiesel (Yusuf Chisti, 2007)	1 litre palm oil = $0.52	1 litre from microalgae produced in photobioreactor = $2.80

4. Future research plans on regional modelling of biofuels

a) Multi-sectoral IO/SAM databases for Scotland and Northern Ireland
   - Identification of possible “marine biofuels sector” under three scenarios for the form of development
   - Model scenarios through case studies at local/regional levels

b) Identification of regional supply-chain for biofuels from algae

c) Modelling of economic impacts in multi-sector, multi-region CGE framework, with technology disaggregated SAMs

Project runs from October 2009 to September 2012

BioMara

Thank you

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