Bio-Economy Input Output (BIO) Model: Development and Applications

Eoin Grealis[1], Cathal O'Donoghue[2],
[1]*Socio-Economic Marine Research Unit*
[2]*Rural Economy Development Programme, Teagasc*

Overview

- What is the Bio-Economy and why do we care?
- I-O Modelling and the Leontief Matrix
- Process of Disaggregation
- Key Assumptions
- Applications
- Trade offs
- Conclusions

What is the Bio-Economy?

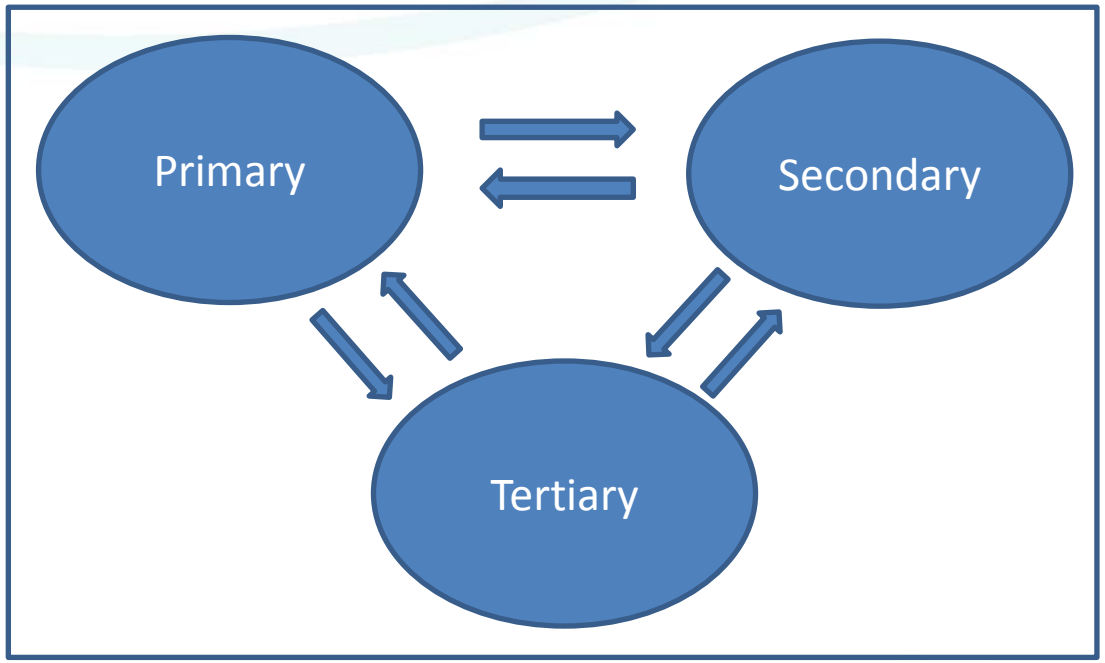
- Not just about the Bio-tech sector
- Economy built upon natural resources (Land and Ocean)
- Indigenous industry – physically tied to a domestic resource
- Think not just in terms of sectors but in terms of value chains
- Suppliers of Inputs? Predominantly domestic or imports?
- Rely more heavily on domestic local resources when compared to more mobile tertiary sectors.

I-O Modelling for Macroeconomic Policy Analysis

No sector of the Economy is an island!

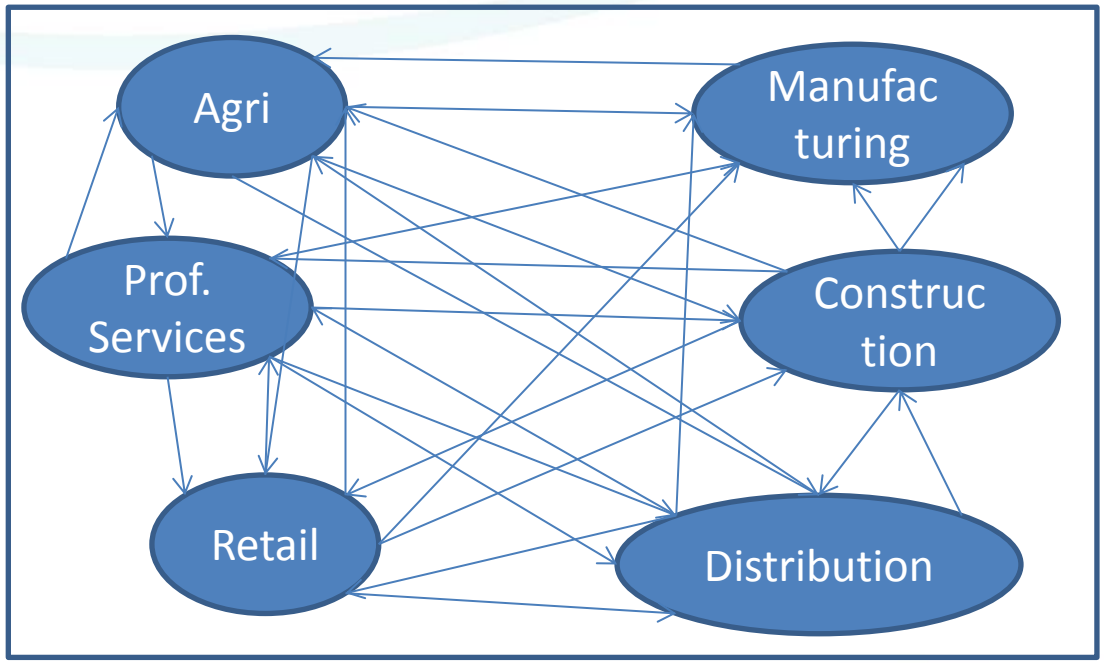
I-O Modelling for Macroeconomic Policy Analysis

Series of interdependent processes



The Economy is Complex

Input-Output modelling conceptualises the production economy as a highly connected system of interdependent processes (Leontief, 1973)



The Economy is Really Complex!!

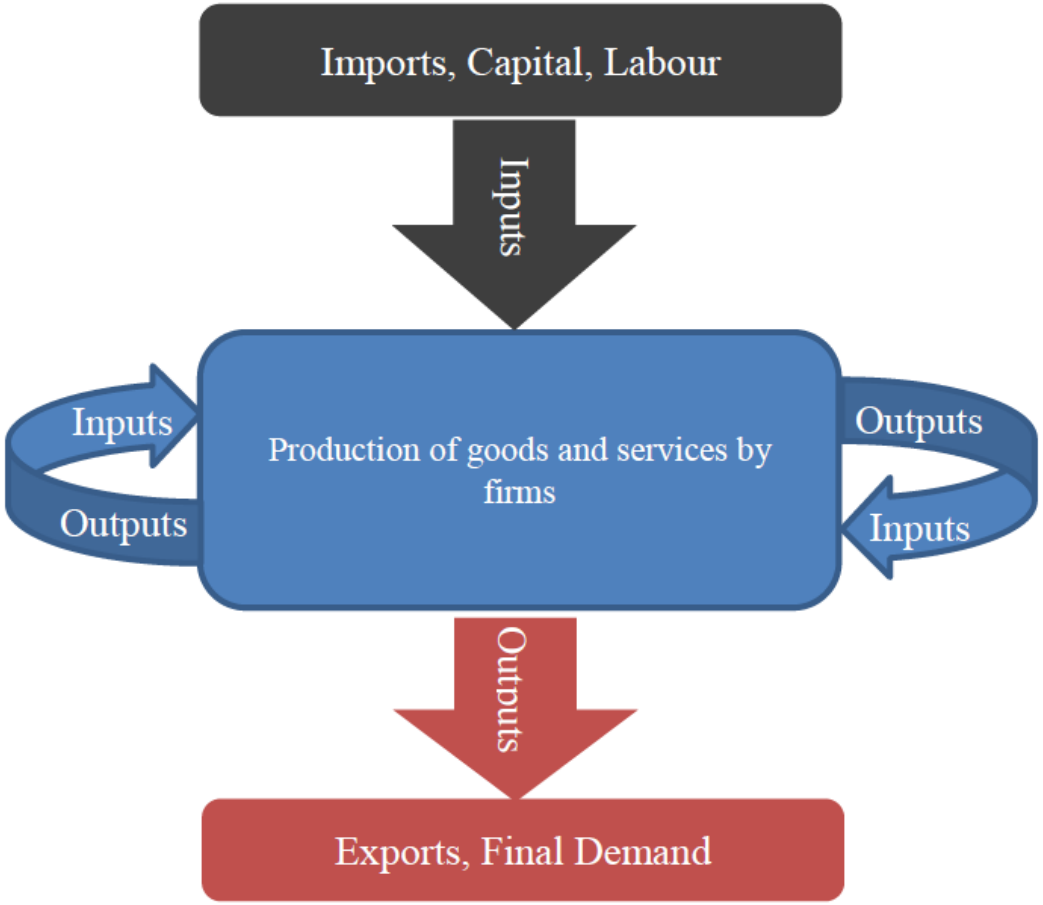
I-O Modelling for Macroeconomic Policy Analysis

The butterfly effect!

- Changes in one sector of the economy will have knock on effects in the rest of the economy
- What will be the magnitude of that change and which areas of the economy will be most effected?
- I-O analysis provides a framework under which we can attempt to answer these questions

Input-Output Analysis

- I-O Analysis can assist policy makers by identifying the key relationships allowing for the targeting of investment/assistance/R&D funding given limited resources
- Attempts to capture the circular flow of economic activity
- Analysis performed through the use of Input-Output tables



Input-Output Tables

- Summarise the source of inputs and the destination of outputs for all production sectors of the economy
- Provides a means of studying:
  - The intensity and direction of relationships between production sectors
  - The relative importance of the different factors of production used by each sector

Input-Output Tables

- 2010 Symmetric Input-Output Table CSO (2014)
  - Columns represent the source of product inputs
  - Rows represent destination of outputs

Total Product Inputs = Total Product Outputs

Products (€m)	Agriculture, forestry and fishing	Manufacturing	Services	Total inter-industry	Final Demand	**Total outputs (= total domestic supply in Table 1)**
Products (€m)						
Agriculture, forestry and fishing	975	3,173	172	4,321	2,041	**6,362**
Manufacturing	501	4,451	5,346	10,298	86,438	**96,736**
Services	638	8,108	62,894	71,640	161,650	**233,290**
Total intermediate consumption	2,118	15,733	68,412	86,263	250,129	**336,391**
Imports and Taxes less subsidies	2,121	47,373	57,568	107,062	36,294	**143,356**
Total consumption at purchasers' prices	**4,240**	**63,106**	**125,979**	**193,325**	**286,423**	**479,747**
Gross Value added	2,122	33,634	107,310	143,066		
Total inputs (=Total domestic supply row in Table 1)	**6,362**	**96,740**	**233,290**	**336,391**		

NUI Galway OÉ Gaillimh · Marine Institute Foras na Mara · eagasc Agriculture and Food Development Authority · SEMRU Socio-Economic Marine Research Unit

Leontief Inverse Matrix

Using Matrix Algebra we can express the Input-Output table in the following way:

$$x = Ax + d$$

where:

$$x = total\ output$$

$$A = matrix\ of\ input\ coefficients$$

$$d = final\ demand$$

We want to find a unified expression for total output “x”

Leontief Inverse Matrix

$$x = Ax + d$$

https://math.dartmouth.edu/archive/m22f06/public_html/leontief_slides.pdf

$$x = (I - A)^{-1}d$$

Leontief Inverse Matrix is defined as $(I-A)^{-1}$

$A = a_{ij} = \frac{z_{ij}}{x_{ij}}$ *matrix of input coefficients for sectors i-j*

z_{ij} = intermediate demand for inputs between sector *i* and the supply sector *j*

x_{ij} is the final output for sector *i*

Leontief Inverse Matrix

- *A* matrix expresses the links between the various sectors of the economy in proportionate terms rather than absolute (or nominal) terms thus revealing the combined input requirements to produce one unit of output

Products	Agriculture, forestry and fishing	Manufacturing	Services
Products			
Agriculture, forestry and fishing	0.15	0.03	0.00
Manufacturing	0.08	0.05	0.02
Services	0.10	0.08	0.27
Total intermediate consumption	0.33	0.16	0.29
Imports and Taxes less subsidies	0.33	0.49	0.25
Gross Value added	0.33	0.35	0.46
Total	1	1	1

2010 "A" Matrix
Source: Supply, Use Input and Output Tables CSO (2014)

Leontief Inverse Matrix

- Leontief Inverse Matrix $(I-A)^{-1}$represents the total direct and indirect output per unit of exogenous final demand for each sector

Products	Agriculture, forestry and fishing	Manufacturing	Services
Products			
Agriculture, forestry and fishing	1.19	0.04	0.00
Manufacturing	0.10	1.05	0.03
Services	0.17	0.13	1.37
Output Multipliers	**1.46**	**1.22**	**1.41**

2010 $(I-A)^{-1}$ *Matrix*

Source: Supply, Use Input and Output Tables CSO (2014)

Disaggregating the Bio-Economy

- Symmetric I-O table for Ireland (2010)
  - 58*58 matrix of product inputs and flows
  - Product classification aggregated to broad NACE code categories determined by the CSO
  - BIO sectors must be disaggregated from their parent categories in order to analyse the each sectors relative importance in the wider economy

- Requires detailed information on the sources of inputs and destination of outputs for various marine sectors collated from a number of different data sources

Disaggregation of BIO Sectors

Sector	NACE Codes	Sub-Sector	Primary Data Sources
Agriculture	1-3	26 sector disaggregation	NFS
Sea Fishing	03.1	Sea Fishing	BIM
Aquaculture	03.2	Aquaculture	BIM/SEMRU
Oil &Gas	06.1, 8.12 & 09.9	Oil &Gas	CIP
Food Processing	10-12	9 sector Disaggregation	CIP
Seafood Processing	10.2	Seafood Processing	CIP
Marine Manufacturing Engineering and Construction	30.1	Marine Transport Equipment	CIP
	33.15	Marine Repair/Installation	CIP
	42.91	Marine Construction	BCI
	71	Marine Engineering	SEMRU
Marine Retail Trade	47.23	Marine Retail Trade	ASI/SEMRU
Marine Shipping and Transport	50.1 & 50.2	Marine Water Transport Services	ASI
	52	Marine Warehousing	ASI
	77.34	Marine Rental & Leasing Services	ASI
Marine Tourism	55-56,79	Marine Tourism	SEMRU/Fáilte Ireland

NUI Galway OÉ Gaillimh

Marine Institute Foras na Mara

eagasc Agriculture and Food Development Authority

SEMRU Socio-Economic Marine Research Unit

Disaggregating the Bio-Economy

Products	Agriculture, forestry and fishing	Manufacturing	Services	**Total inter-industry**	Final Demand	Total outputs (= total domestic supply in Table 1)
Products						
Agriculture, Forestry and Fishing	975	3,173	172	**4,321**	2,041	6,362
Manufacturing	501	4,451	5,346	**10,298**	86,438	96,736
Services	638	8,108	62,894	**71,640**	161,650	233,290
Total intermediate consumption	2,118	15,733	68,412	**86,263**	250,129	336,391
Imports and Taxes less subsidies	2,121	47,373	57,568	**107,062**	36,294	143,356
Total consumption at purchasers' prices	**4,240**	**63,106**	**125,979**	**193,325**	**286,423**	479,747
Gross Value added	2,122	33,634	107,310	**143,066**		
Total inputs (=Total domestic supply row in Table 1)	**6,362**	**96,740**	**233,290**	**336,391**		

Disaggregating the Bio-Economy

Products	Agriculture, forestry and fishing	Manufacturing	Seafood Processing	Services	**Total inter-industry**	Final Demand	Total outputs (= total domestic supply in Table 1)
Products							
Agriculture and Forestry & Fishing	975	3,173-H	*H*	172	**4,321**	2,041	6,362
Manufacturing	501-*A*	4,451-(B+C+I)	*I*	5,346-D	**10,298-E**	86,438-F	96,736-G
Seafood Processing	*A*	*B*	*C*	*D*	***E***	*F*	*G*
Services	638-*G*	8,108 –J	*J*	62,894	**71,640**	161,650	233,290
Total intermediate consumption	2,118-*H*	15,733 –K	*K*	68,412	**86,263**	250,129	336,391
Imports and Taxes less subsidies	2,121-*I*	47,373 –L	*L*	57,568	**107,062**	36,294	143,356
Total consumption at purchasers' prices	**4,240**	**63,106-M**	***M***	**125,979**	**193,325**	**286,423**	479,747
Gross Value added	2,122	33,634-M	*N*	107,310	**143,066**		
Total inputs (=Total domestic supply row in Table 1)	**6,362**	**96,740-O**	***O***	**233,290**	**336,391**		

NUI Galway OÉ Gaillimh

Marine Institute Foras na Mara

eagasc Agriculture and Food Development Authority

SEMRU Socio-Economic Marine Research Unit

Key Assumptions

- One Sector, One Product
- Import ratios from CSO, SUIOT, (Table 10) were applied to intermediate consumption
- Manual Balancing
  - Pragmatic decisions in consultation with industry experts
  - National Input-Output table taken as the gold standard
  - Remaining imbalances allocated to Final Demand
  - Cross Entropy and GRAS investigated but not used.

HOOW Targets

Eoin Grealis[1], Amaya Vega[1], Cathal O'Donoghue[2], Stephen Hynes[1]
[1]*Socio-Economic Marine Research Unit*
[2]*Rural Economy Development Programme, Teagasc*

Sector	Ocean Wealth 2020 Target*
Seafood (fisheries, aquaculture, seafood processing)	€1,000 million
Maritime Commerce and Ship Leasing	€2,600 million
Marine and Coastal Tourism and Leisure (including Cruise Tourism)	€1,500 million
Marine ICT and Biotechnology	>€61 million
Ports and Maritime Transport Services, Maritime Manufacturing, Engineering, Offshore Oil and Gas, other marine industries	>€1,200 million

HOOW Targets

	Seafood	Fishing	Aquaculture	Seafood Processing
Output €m	676	164	123	390
HOOW Target €m	1,000	242	181	577
Required Increase €m	324	79	59	187

	Maritime Commerce and Transport	Oil &Gas	Marine Manu, Eng & Const.	Marine Retail	Shipping and Transport
Output €m	1,566	126	111	58	1,272
HOOW Target €m	3,800	305	269	140	3,086
Required Increase €m	2,234	179	158	82	1,814

Application

Impacts of Reaching HOOW Targets: Output

	Fishing	Aquaculture	Oil &Gas	Seafood Processing	Marine Manu, Eng & Const.	Marine Retail	Shipping and Transport	Marine Tourism	Total €M
Output Multiplier	1.40	1.41	1.57	1.65	1.74	1.50	2.01	1.60	-
2010 Output €m	164	123	126	390	111	58	1,272	723	2,965
HOOW Target €m	242	181	305	577	269	140	3,086	1,500	6,300
Required €m (Direct Impact)	79	59	179	187	158	82	1,814	777	3,335
Indirect Impact €m	31	24	101	122	118	41	1,841	468	2,745
Total Impact €m	273	205	407	697	386	181	4,927	1,968	9,045

Application

Impacts of Reaching HOOW Targets: Output

	Fishing	Aquaculture	Oil &Gas	Seafood Processing	Marine Manu, Eng & Const.	Marine Retail	Shipping and Transport	Marine Tourism	Total €M
Output Multiplier	1.40	1.41	1.57	1.65	1.74	1.50	2.01	1.60	-
2010 Output €m	164	123	126	390	111	58	1,272	723	2,965
HOOW Target €m	242	181	305	577	269	140	3,086	1,500	6,300
Required €m (Direct Impact)	79	59	179	187	158	82	1,814	777	3,335
Indirect Impact €m	31	24	101	122	118	41	1,841	468	2,745
Total Impact €m	273	205	407	697	386	181	4,927	1,968	9,045

NUI Galway OÉ Gaillimh

Marine Institute Foras na Mara

eagasc Agriculture and Food Development Authority

semru Socio-Economic Marine Research Unit

Application

Impacts of Reaching HOOW Targets: Output

	Fishing	Aquaculture	Oil &Gas	Seafood Processing	Marine Manu, Eng & Const.	Marine Retail	Shipping and Transport	Marine Tourism	Total €M
Output Multiplier	1.40	1.41	1.57	1.65	1.74	1.50	2.01	1.60	-
2010 Output €m	164	123	126	390	111	58	1,272	723	2,965
HOOW Target €m	242	181	305	577	269	140	3,086	1,500	6,300
Required €m (Direct Impact)	79	59	179	187	158	82	1,814	777	3,335
Indirect Impact €m	31	24	101	122	118	41	1,841	468	2,745
Total Impact €m	273	205	407	697	386	181	4,927	1,968	9,045

NUI Galway OÉ Gaillimh

Marine Institute Foras na Mara

eagasc Agriculture and Food Development Authority

semru Socio-Economic Marine Research Unit

Application

Impacts of Reaching HOOW Targets: Output

	Fishing	Aquaculture	Oil &Gas	Seafood Processing	Marine Manu, Eng & Const.	Marine Retail	Shipping and Transport	Marine Tourism	Total €M
Output Multiplier	1.40	1.41	1.57	1.65	1.74	1.50	2.01	1.60	-
2010 Output €m	164	123	126	390	111	58	1,272	723	2,965
HOOW Target €m	242	181	305	577	269	140	3,086	1,500	6,300
Required €m (Direct Impact)	79	59	179	187	158	82	1,814	777	3,335
Indirect Impact €m	31	24	101	122	118	41	1,841	468	2,745
Total Impact €m	273	205	407	697	386	181	4,927	1,968	9,045

NUI Galway OÉ Gaillimh

Marine Institute Foras na Mara

eagasc Agriculture and Food Development Authority

SEMRU Socio-Economic Marine Research Unit

Application

Impacts of Reaching HOOW Targets: Employment

	Fishing	Aquaculture	Oil &Gas	Seafood Processing	Marine Manu, Eng & Const.	Marine Retail	Shipping and Transport	Marine Tourism	Total
Emp. Multiplier	1.49	1.38	2.37	2.36	1.84	1.59	2.79	1.49	-
Jobs/€M	12.7	7.8	2.9	4.1	6.6	4.4	3.3	7.6	-
2010 Employment	2,084	952	359	1,586	726	252	4,137	5,497	15,593
2010 Output €m	€164	€123	€126	€390	€111	€58	€1,272	€723	€2,965
HOOW Increase €m	€79	€59	€179	€187	€158	€82	€1814	€777	€3,335
Direct Jobs	1,000	457	512	761	1,035	359	5,901	5,908	15,932
Indirect Jobs	487	173	701	1,033	874	212	10,567	2,881	16,927
Total	1,486	629	1,213	1,794	1,910	571	16,467	8,789	32,859

NUI Galway OÉ Gaillimh

Marine Institute Foras na Mara

eagasc Agriculture and Food Development Authority

SEMRU Socio-Economic Marine Research Unit

Application

Impacts of Reaching HOOW Targets: Employment

	Fishing	Aquaculture	Oil &Gas	Seafood Processing	Marine Manu, Eng & Const.	Marine Retail	Shipping and Transport	Marine Tourism	Total
Emp. Multiplier	1.49	1.38	2.37	2.36	1.84	1.59	2.79	1.49	-
Jobs/€M	12.7	7.8	2.9	4.1	6.6	4.4	3.3	7.6	-
2010 Employment	2,084	952	359	1,586	726	252	4,137	5,497	15,593
2010 Output €m	€164	€123	€126	€390	€111	€58	€1,272	€723	€2,965
HOOW Increase €m	€79	€59	€179	€187	€158	€82	€1814	€777	€3,335
Direct Jobs	1,000	457	512	761	1,035	359	5,901	5,908	15,932
Indirect Jobs	487	173	701	1,033	874	212	10,567	2,881	16,927
Total	1,486	629	1,213	1,794	1,910	571	16,467	8,789	32,859

NUI Galway OÉ Gaillimh

Marine Institute Foras na Mara

eagasc Agriculture and Food Development Authority

SEMRU Socio-Economic Marine Research Unit

Application

Impacts of Reaching HOOW Targets: Employment

	Fishing	Aquaculture	Oil &Gas	Seafood Processing	Marine Manu, Eng & Const.	Marine Retail	Shipping and Transport	Marine Tourism	Total
Emp. Multiplier	1.49	1.38	2.37	2.36	1.84	1.59	2.79	1.49	-
Jobs/€M	12.7	7.8	2.9	4.1	6.6	4.4	3.3	7.6	-
2010 Employment	2,084	952	359	1,586	726	252	4,137	5,497	15,593
2010 Output €m	€164	€123	€126	€390	€111	€58	€1,272	€723	€2,965
HOOW Increase €m	€79	€59	€179	€187	€158	€82	€1814	€777	€3,335
Direct Jobs	1,000	457	512	761	1,035	359	5,901	5,908	15,932
Indirect Jobs	487	173	701	1,033	874	212	10,567	2,881	16,927
Total	1,486	629	1,213	1,794	1,910	571	16,467	8,789	32,859

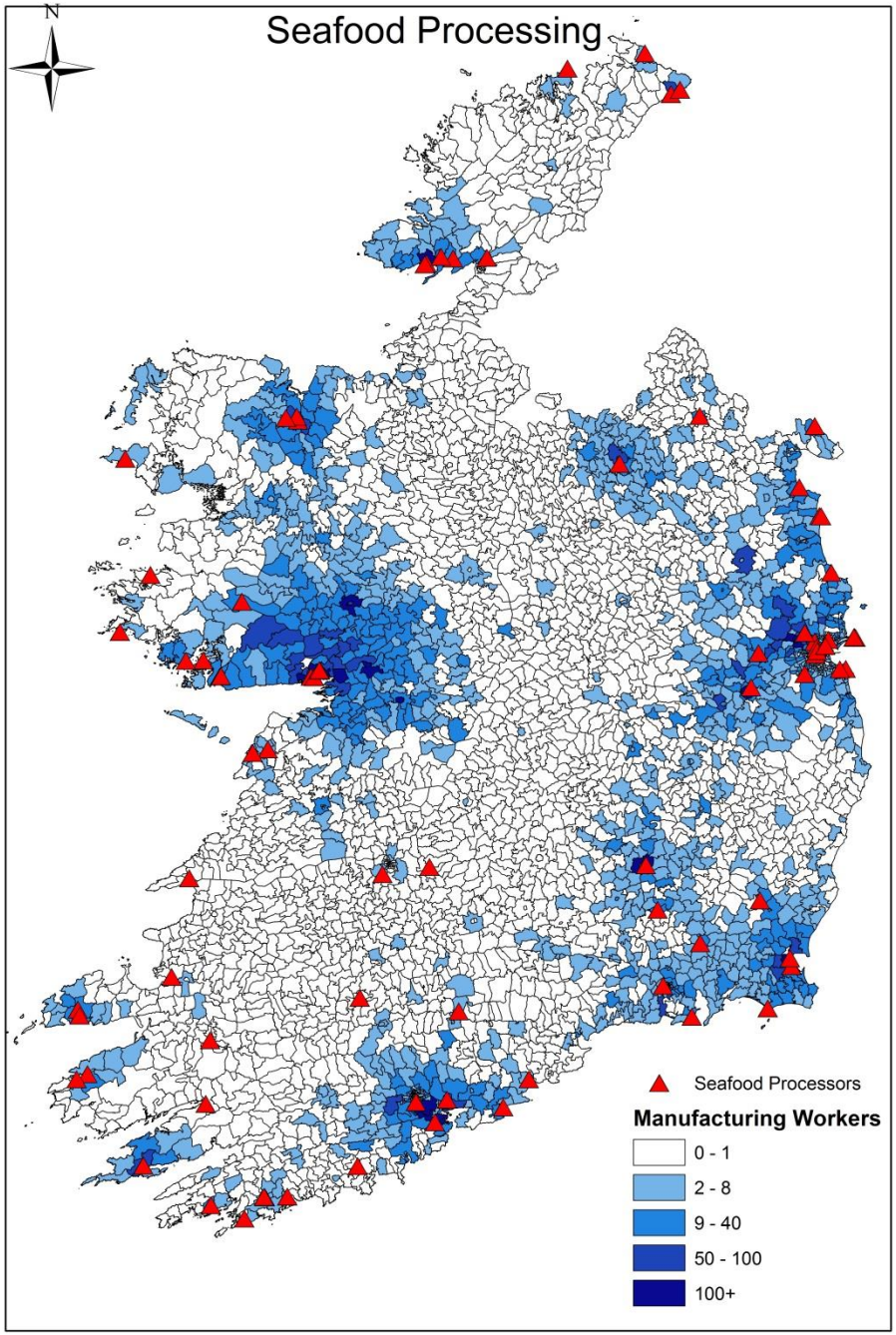
NUI Galway OÉ Gaillimh

Marine Institute Foras na Mara

eagasc Agriculture and Food Development Authority

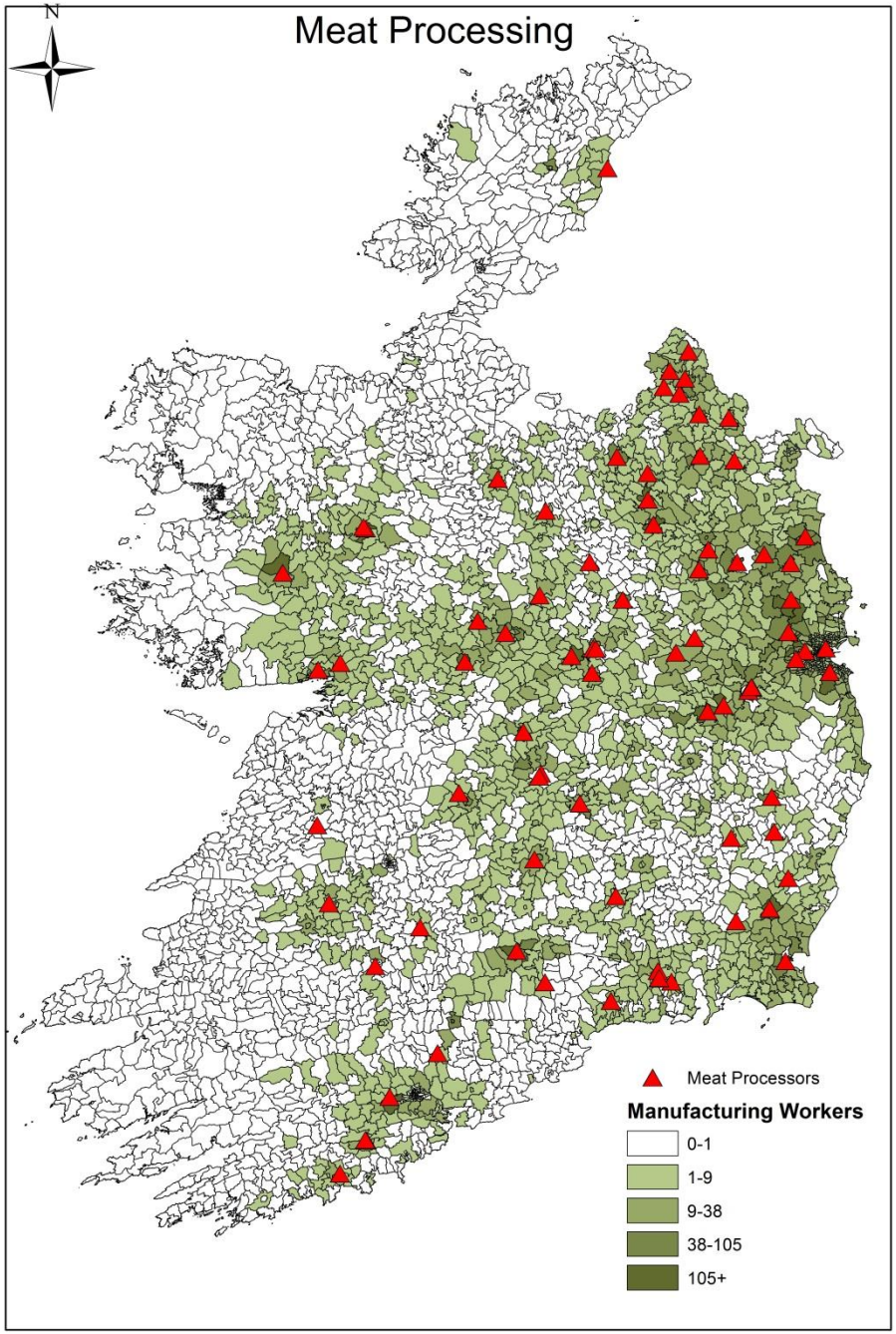
SEMRU Socio-Economic Marine Research Unit

Further Applications



NUI Galway
OÉ Gaillimh

MRU
Marine Research Unit



NUI Galway
OÉ Gaillimh

MRU
Marine Research Unit

Trade Offs/Caveats

- Increase in complexity higher resource costs
- Each additional disaggregation will add 2(n+1) new row and column entries increasing number of assumptions and increasing the balancing challenge
- Greater the level of disaggregation the less confidence we might have in assumption relying on existing input-output ratios
- Average coefficients for the calculation of marine sector employment multipliers. NFS vs. OER
- Non-market values not considered

Trade Offs/Caveats

- Increase in complexity higher resource costs
- Each additional disaggregation will add 2(n+1) new row and column entries increasing number of assumptions and increasing the balancing challenge
- Greater the level of disaggregation the less confidence we might have in assumption relying on existing input-output ratios
- Average coefficients for the calculation of marine sector employment multipliers. NFS vs. OER
- Non-market values not considered

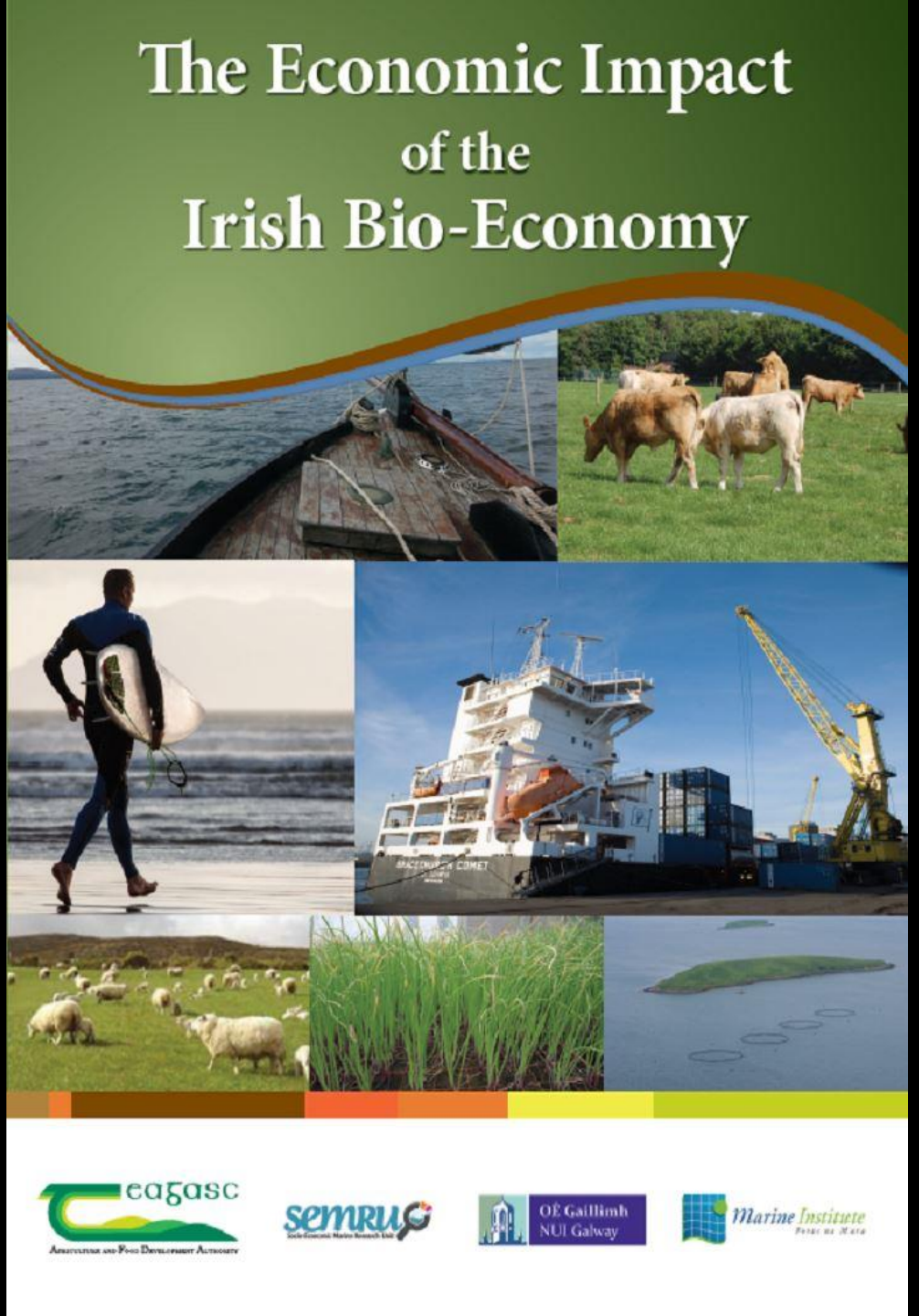
Limitations

- BIO is a model of reality, not reality itself
- It does not purport to be gold standard when compared to the National accounts/NFS or HBS
- It relies on assumptions and expert judgement as we do not have the data to model all flows.
- “All models are wrong, some are useful”. *George E.P. Box*
- The goal is to improve our understanding of the Bio-Economy and it’s sub-sectors placement in the wider economy.

Conclusions

- Bio-Economy Input-Output model has been formed enabling the creation of the Leontief Inverse matrix and the performance of multiplier analyses.
- Provides a structured approach to analysis the Bio-Economy w.r.t the rest of the economy
- Constantly evolving process.
  - The identification/inclusion of new (BIO) areas
  - New data sources/restructuring of existing data
  - Refinement of existing assumptions
- Consistency of measurement, and additional years of observation will be required from the marine sector the estimation of more reliable employment multipliers in the future.

Available on the Teagasc and SEMRU Websites
www.teagasc.ie
www.nuigalway.ie/semru



Key Literature

- Baumol, W.J. (2000) Leontief's Great Leap Forward: Beyond Quesnay, Marx and von Bortkiewicz, Economic Systems Research, 12:2, 141-152.
- Leontief, W. (1973) Structure of the World Economy: Outline of a Simple Input-Output Formulation, Nobel Memorial Lecture, December 11, 1973
- Miller, A. C., Matthews, A., Donnellan, T. and O'Donoghue, C. (2011a) A 2005 Agriculture-Food SAM (Agri Food-SAM) for Ireland. IIIS.
- Miller, R.E. & Blair, P.D. (2009) Input-Output Analysis: Foundations and Extensions, Cambridge University Press.
- Morrissey, K. & O'Donoghue, C. (2013) The role of the marine sector in the Irish national economy: An input–output analysis. Marine Policy, 37, 230-238.

Thank you

Questions?

eoin.grealis@nuigalway.ie

NUI Galway
OÉ Gaillimh

Marine Institute
Foras na Mara

teagasc
Agriculture and Food Development Authority

SEMRU
Socio-Economic Marine Research Unit