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NiReMS (National Institute Regional Modeling System):

A regional model at household level combining spatial econometrics with dynamic microsimulation

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PIER, Bank of Thailand, June 2024

Why does spatial structure matter?

Policy requires clean and robust quantification of spatial direct and indirect effects – having an agnostic and open view of spatial structure helps

"UK 2070 Commission is an independent inquiry into the deep-rooted spatial inequalities within the United Kingdom. There is no longer any real debate about the scale of these inequalities. Whether in terms of health, housing or productivity, it is now accepted that the UK is one of the most regionally imbalanced economies in the industrialised world. Inequality blights the prospects of future generations of the UK. This means that the economic potential of large parts of the UK is not being realised, creating an imbalance of wealth and opportunity. Inequality has created social division." (Lord Kerslake, 2020)

"The UK's Productivity Problem: Hub No Spokes" (Andy Haldane, 2018).

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... but economic theory as such has very little to say

- Foerster, Sarte & Watson (2011); Holly & Petrella (2012):
 - Input-output (I-O) linkages serve as a powerful amplifier of otherwise independent shocks.
- Acemoglu, Carvalho, Ozdaglar & Tahbaz-Salehi (2012); Carvalho (2014):
 - Intersectoral I-O linkages induce micro shocks to lead to aggregate fluctuations
 - Structure of I-O linkages matter substantially, but not so much sparsity
 - Sizable aggregate volatility if there is significant asymmetry in sectors within I-O matrix
- (New/Traditional) Economic Geography
 - Constant returns to scale implies convergence
 - Increasing returns to scale leads to agglomeration without much (any?) possibility of "levelling up"
- Spatial econometrics emphasizes spatial direct/indirect effects
- Multi-regional I-O models emphasize trade connections

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Unsecured Debt – Deepening disparities

Backdrop



Examples of NiReMS output

Northern Ireland with and w/o Protocol

Figure 2.13 GVA in Northern Ireland, with and without the Protocol (per cent difference from 2020Q4)



Policy urgency following COVID-19

"COVID-19 and Brexit shocks are projected to have substantial impacts upon distributions. ... 'COVID-19 was never the best leveller', essentially exacerbating entrenched inequalities and vulnerabilities already existing within the UK society, sectors and regions" (NIESR, 2020).

- Leading expertise in
 - ► Business Cycle in the Cross-section/Macro-founded microeconomics
 - Structural/Causal Modelling in Social Sciences, incl. Big Data/ML
 - Spatial/network contexts UK's regions, households & wellbeing
- NiReMS (National Inst Regional Modelling System) 3 components
 - Structural regional macro: DSGE (in reduced form VAR-VECM form)
 - Spatial econometrics: Structural spillovers global and local estimated spatial weights
 - Heterogenous agents: Transition representative to heterogenous by dynamic microsimulation
 - Calibration: match up to macro/sectoral projections NiGEM/NiSEM
 - Adapted to Big Data Machine Learning technology

Why/How are countries (regions) connected?

- Current wisdom: Countries/ regions are connected on an inter-regional network
 - Cross country growth regressions MUST include spatial interactions not only fixed effects
 - Fingleton and López-Bazo (2006); Eberhardt and Teal (2011); Corrado and Fingleton (2012); Ertur and Musolesi (2017); Debarsy and Ertur (2019); Le Gallo and Fingleton (2021)
- But why/how?

Multi-regional modeling

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- New Economic Geography mobility/access to factor inputs? (Behrens and Thisse, 2007)
- Technology diffusion very influential (... but why?) (Ertur and Koch, 2007, 2011; Corrado and Fingleton, 2012; Ertur and Musolesi, 2017)
- Trade surprisingly little focus except measurement of W
- Labour mobility (Ditzen and Bhattacharjee, 2014; Ditzen, 2018)
- Trade and labour mobility Input-Output UK NIReMS (National Institute Regional Modelling System – Bhattacharjee et al., 2021)
- Multiple channels DSGE (Wasseja, Bhattacharjee & Christev, 2022)

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Ertur & Koch (2007, 2011)

• Firms production follows a Cobb-Douglas production function with capital and labour as inputs.

$$Y_{it} = \mathbf{A}_{it} \mathcal{K}_{it}^{\alpha} \mathcal{N}_{it}^{1-\alpha}, \quad 0 < \alpha < 1, \tag{1}$$

• Technological progress **A** follows Equation (2) where Ω is the exogenous part of technology.

$$\mathbf{A}_{it} = \Omega_t k_{it}^{\phi} \prod_{j \neq i}^{N} \mathbf{A}_{jt}^{\rho w_{ij}}$$
⁽²⁾

Rewriting the log-version of Equation (2) & solving for A: •

$$\mathbf{A} = (I - \rho \mathbf{W})^{-1} \Omega + \phi (I - \rho \mathbf{W})^{-1} k$$

$$\mathbf{A} =
ho \mathbf{W} \mathbf{A} + \phi k + \Omega$$
 ; $|
ho| < 1, ||\mathbf{W}|| < 1$

Spatial regional macroeconomy model I

NiReMS

- Baseline macro (DSGE?) models
 - Smets & Wouters (2007) as modified by Gali, Smets & Wouters (2012)

 unemployment
 - Open economy models: Gali & Monacelli (2005) modified by Wasseja, Bhattacharjee & Christev (2022) – going beyond terms of trade ...
 - ... Technology spillovers, mobility of factor inputs (labour/capital)
 - But we have regions negligible terms of trade, price differentials need modifications
 - ▶ 4 state variables: Output/GVA, Consumption, Employment, Wages
- Typical small open economy region inhabited by representative households seeking to maximise

$$\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t u(C_t,L_t)$$

Spatial regional macroeconomy model II

NiReMS

- Spatial lag dependence?
 - Cobb-Douglas production technology with potential technology spillovers: Ertur & Koch (2007), Wasseja et al. (2022) – spatial lag in output
 - Consumption: negligible terms of trade, but output consumed across region boundaries – spatial lag
 - Labour: mobile spatial lag
 - Wages: Differentials negated by labour mobility spatial lag
- Potentially 2 equilibrium relations
 - Consumption and Output (plus price?)
 - "Wage markup" above marginal rate of substitution a la Smets & Wouters (2007)
- Finite order VAR/VECM representation: so-called ABCD form (Fernández-Villaverde, Rubio-Ramírez, Sargent & Watson, 2007)

Estimated spatial structure I

• Regional VECM with spatially heterogenous slopes & factor structure:

$$\Delta R_{it} = \alpha_i + \mathbf{W} \Delta R_{it} + \Gamma \begin{bmatrix} \Delta R_{i,t-1} & \Delta_s R_{it} \end{bmatrix} \\ -\Theta \begin{bmatrix} -\gamma & 1 & 0 & 0 \\ -\theta & 0 & 1 & \eta \end{bmatrix} R_{i,t-1} + \Lambda \begin{bmatrix} \Delta R_t^* & \pi_{t-1} \end{bmatrix} + \epsilon_{it}$$

$$\triangleright R_{it} = \begin{bmatrix} \ln Y_{it} & \ln C_{it} & \ln w_{it} & \ln L_{it} \end{bmatrix}$$

- Δ and Δ_s : (temporal) first difference and seasonal (fourth) differences
- $R_t^* = \begin{bmatrix} \ln Y_t^* & \ln C_t^* & \ln w_t^* & \ln L_t^* \end{bmatrix}'$ national aggregates
- π_{t-1} denotes lagged inflation (national)
- Γ: Temporal short run dynamics
- Θ: Partial adj temporal eqbm
- Λ: Factor structure/potential strong dependence (Pesaran 2006 etc)
- W: Spatial short run dynamics econometric/statistical challenge

Estimated spatial structure II

- Estimation of \boldsymbol{W} partial identification hard problem
 - Bhattacharjee & Jensen-Butler (2013): Symmetry not applicable
 - Basak et al. (2017): recursive structure
 - High dimensions & sparsity
 - * Ahrens & Bhattacharjee (2015): IV-LASSO with exog instruments
 - ★ Cai et al. (2019): pre-filtering & GMM-LASSO
 - ★ Li & Bhattacharjee (2023): OCMT as alternative to LASSO
- Bhattacharjee & Holly (2013)
 - Spatial network structure estimated using repeated instrument validity (overidentifying restrictions) tests
 - Weak dependence CD test on residuals (Pesaran, 2015)
 - Take regional Y & L projections into microsim

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Enhancement and integration

Examples of NiReMS output

Estimated spatial structure III



Microsimulation – LINDA (Lifetime INcome Distributional Analysis)

- Microsim generates (pseudo) panel data for a simulated population
- Starting from a representative sample of UK households/persons
 - ▶ For UK Wealth and Assets Survey (WAS), 2017-18
 - Can include observed variables & others (imputed)
- Evolving cross-section projected forward through time
- Necessary to consider implications for nationally representative statistics, including distributional issues
- Model is freely available for download from www.simdynamics.org
 - But, ongoing enhancements Szendrei and Bhattacharjee (2021)
 - Get LINDA dynamics to speak to aggregate projections (NiGEM)
 - Model potential (not current) changes to tax/welfare systems
 - ★ Modelling alternate tax/welfare systems (HM Treasury)
 - * Prospects for Universal Basic Income (Welsh Govt)
 - * Progressive consumption tax (Standard Life Foundation)

Microsimulation – LINDA (Lifetime INcome Distributional Analysis) NIESR (2016), van de Ven (2017)

- Representative agent to Heterogenous
- Building upon research on latent networks and microsimulation
- Distributional Implications of Policy & Shocks
- A spectrum of behavioural assumptions



Projections



van de Ven (2017)

Static microsimulation and reduced form models

- Non-stochastic characteristics
 - Year of birth Age Retirement Gender Ethnicity Location
- Reduced form models
 Labour market status
 ISA investments
 Benefits
 Child birth
- Labour income Business assets Student status Child gender
- Education level Pension wealth Financial/Other income HH formation/dissolution

- Transition probabilities
 - Migration Employment sector Carer status Time of death
- Relationship status Health status

Dynamic microsimulation

- Dynamic optimisation based on incomes over the lifecycle
 - Consumption/Savings and Labour/Leisure choice dynamically optimised – Computational maths – highly challenging
 - Everything else in lifecourse changes through transition probabilities (static microsim)

• Preferences (indiv *i*; *a*/*A* : current/death age; *d*/*w* : savings/wealth)

$$U_{i,a} = \frac{1}{1+\gamma} \mathbb{E}_{a} \Sigma_{j=a}^{A} \delta^{j-a} \left\{ \phi_{j-a,a}^{b} \left[u(c_{i,j}, l_{i,j})^{1-\gamma} \right. \right. \\ \left. + \psi \max(1, d_{i,j}^{ISA})^{1-\gamma} \right] + (1 - \phi_{j-a,a}^{b}) \zeta \max(1, w_{i,j}^{+})^{1-\gamma} \right\}$$

Budget constraints

$$w_{t+1} = w_t + \tau (rw_t + h_t(1 - l_t)) - c_t$$

Evolution of wages

$$\ln h_{t+1} = \beta \ln h_t + \lambda (1 - l_t) + \epsilon_t$$

Dynamic microsimulation policy functions I



Single adult household labour and consumption decisions (assets/cons. in £'000s)

Dynamic microsimulation policy functions II



raction of time worked (Spouse

Couple household labour decisions (assets in £'000s; Blue: 0%; Yellow 100%)

10

NiReMS – National Institute Regional Modelling System

Bhattacharjee, Lisauskaite, Pabst & Szendrei (2021)

- Alignment with macro dynamics & policy counterfactuals
 - Get LINDA dynamics to speak to aggregate projections (NiGEM)
 - Model potential (not current) changes to tax/welfare systems
- Spatial econometric model ONS data (GOR level)
 - Global shocks (COVID/Brexit) Factor models
 - Local shocks inter-regional spillovers
 - Park-Hewings, Bhattacharjee/Chakravorty/Maiti
 - Fed Chicago model for US MidWest States
- Projections at regional level
 - Output (GVA), Employment (E), Productivity/Wages
 - Output growth \Rightarrow Unemp rate (U)
 - $U + E \Rightarrow$ Participation/activity rates
 - Validated against sectoral composition (NiGEM+NiSEM)
 - Wages + U \longrightarrow Input into microsim
- Reported in Regional chapter of NIESR UK Outlooks
 - Regional GVA, Employment, Productivity
 - Destitution and Lower decile HH incomes

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Examples of NiReMS output •••••••

Permanent scarring?



Wage dynamics: Does heterog. agents make a difference?



Impact of Covid-19 and Universal Credit uplift on distbn of household consumption 2022-23 (as of Nov'21)



NiGEM, NiReMS and LINDA

HH consumption, 2022-23 (by quantile) relative to COVID

Additional consumption in counterfactuals



Bhattacharjee, Pabst, Szendrei, Hewings NiReMS & NIESR Regional Projections

Examples of NiReMS output

Cost of living

Figure 2.1 Effect of inflation and the May 2022 support measures on Household Budgets



Source: LINDA

Percent of Households in Destitution (JRF defn, income)

Figure 3.7 COVID+Brexit/No shocks ratio of destitution for 2020 and 2022

2020

2022





Source: ONS, WAS6, NiReMS, LINDA

Who are the unemployed?

Unemployed persons by gender and age-group

	2019-20	2020-21	2021-22	2022-23	2020-21	2021-22	2022-23	
					% chang	% change compared to 2019-20		
Men								
18-24 years	199,565	311,798	411,471	424,827	56.2%	106.2%	112.9%	
25-49 years	296,824	356,341	246,235	293,580	20.1%	-17.0%	-1.1%	
50-64 years	202,099	222,713	233,020	236,052	10.2%	15.3%	16.8%	
Women								
18-24 years	200,383	218,664	342,055	332,781	9.1%	70.7%	66.1%	
25-49 years	295,653	364,439	325,451	357,563	23.3%	10.1%	20.9%	
50-64 years	129,809	145,776	149,540	153,824	12.3%	15.2%	18.5%	
Total	1,324,333	1,619,731	1,724,215	1,816,587	22.3%	30.2%	37.2%	
Unemployment rate	3.87%	4.77%	5.10%	5.31%				

Source: ONS and NiReMS

Racial distribution: Poverty /destitution

Table 2.2 Destitute households by ethnicity of household head, 2022-23 (per cent)

	Post-Covid with high inflation	Counterfactual (no excess inflation)	Counterfactual (no Covid)
White	3.5%	2.7%	0.7%
Indian	3.6%	2.4%	0.8%
Other South Asian	5.8%	4.8%	0.8%
Black African	5.2%	3.5%	1.7%
Caribbean	5.5%	4.6%	0.9%
UK (aggregate)	3.51%	2.68%	0.67%

Source: LINDA and NiREMS

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Examples of NiReMS output

High impact - Policymakers, Politicians, Press





Ben Chu @BenChu

A statistic in @NIESRorg's recent projections that arguably hasn't received enough attention

They calculate that 1.5 million UK households later this year are facing food and energy bills 'greater than their disposable income'

So literally a choice between heating and eating...

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 2 Outlook for the devolved nations,
 English regions, and UK households
By Arnob Bhattacharjer, Max Mosley, Adrian Polst, and Tibor Szendrei

Rising prices and higher taxes are squeezing bousehold budgets: for 2022-23 we estimate that about 1.5
million households across the UK face food and energy bills greater than their disposable income, with the
fighter trunclence in London and Scotland.

8:27 PM · May 25, 2022

Policy Proposals

- Levelling-Up is Policy Urgent
- In the short term, income sustenance through benefits, as UC uplift and furlough ended in Sept 2021
- In the medium run, retraining & globally-relevant, good, and green jobs vital
- How could higher savings be guided towards investment to promote regional regeneration?
- Can consumption be promoted together with a zero-carbon agenda?
 incentives for adoption of green technologies

Where to next?

- Firm heterogeneity
- Labour market matching labour/leisure/retraining
- Greater spatial granularity city-regions
- Portability?
- Investments and levelling-up?

Thank You Very Much!

Very Happy to Collaborate & Work with colleagues at ISI and beyond Exciting & Challenging Work Continues ...