Sub-National Economic Complexity

Applications to UK Industrial Policy

MPP Thesis

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April 30, 2024

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Regional divides have become a dominant issue in British politics

Figure 1: Boris Johnson.

The UK has significant regional divides. . .

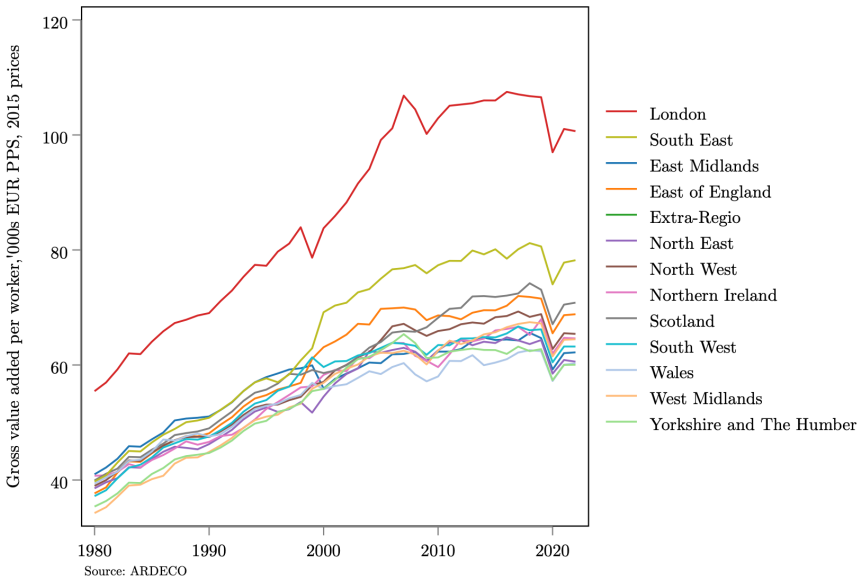


Figure 2: GVA per worker, UK ITL1 regions, 1980-2022.

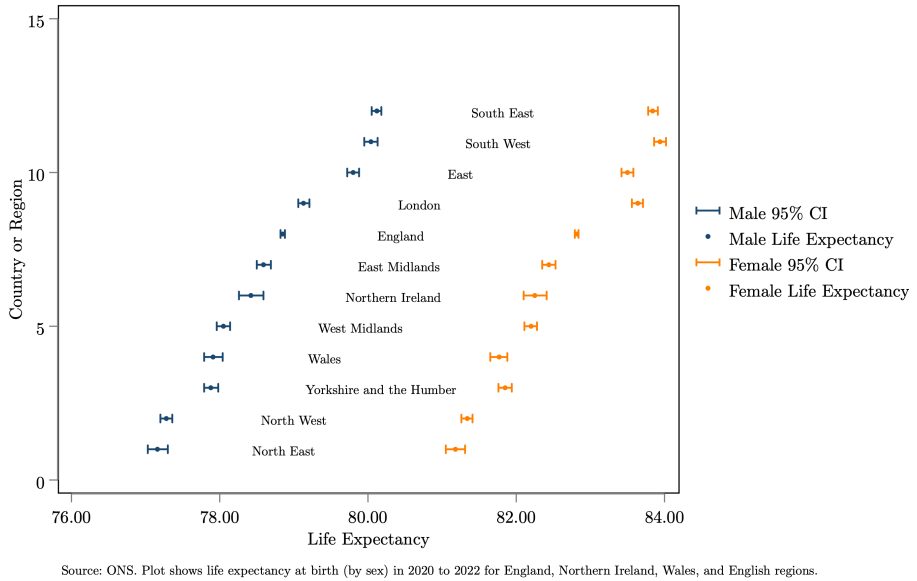


Figure 3: Life expectancy at birth, UK ITL1 regions and countries, 2020-2022.

- Wales, Yorkshire, the North East and North West are low productivity and low life expectancy.

. . . which are large by international standards

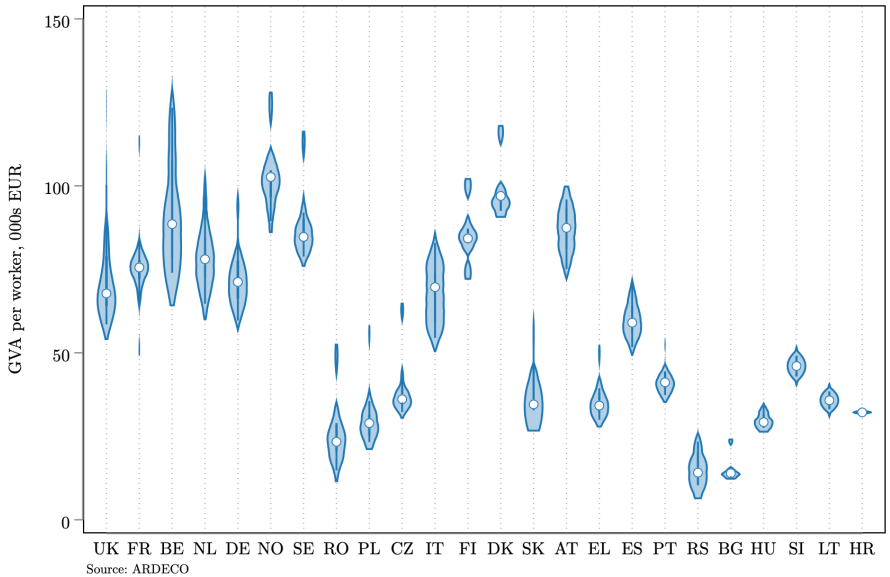


Figure 4: Distribution of GVA per worker, ITL2 regions, 2019.

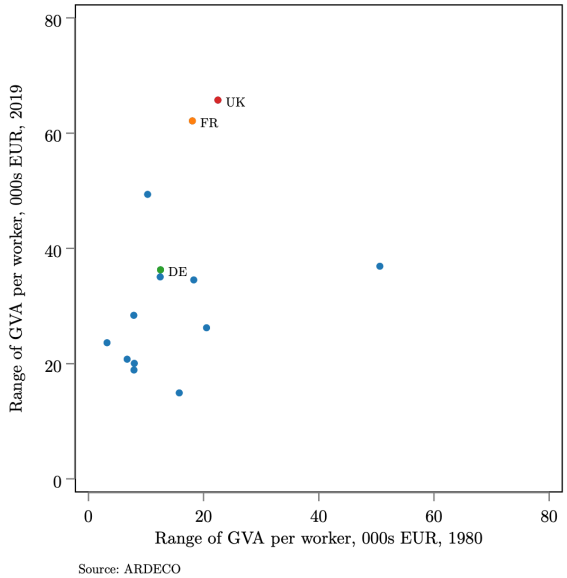
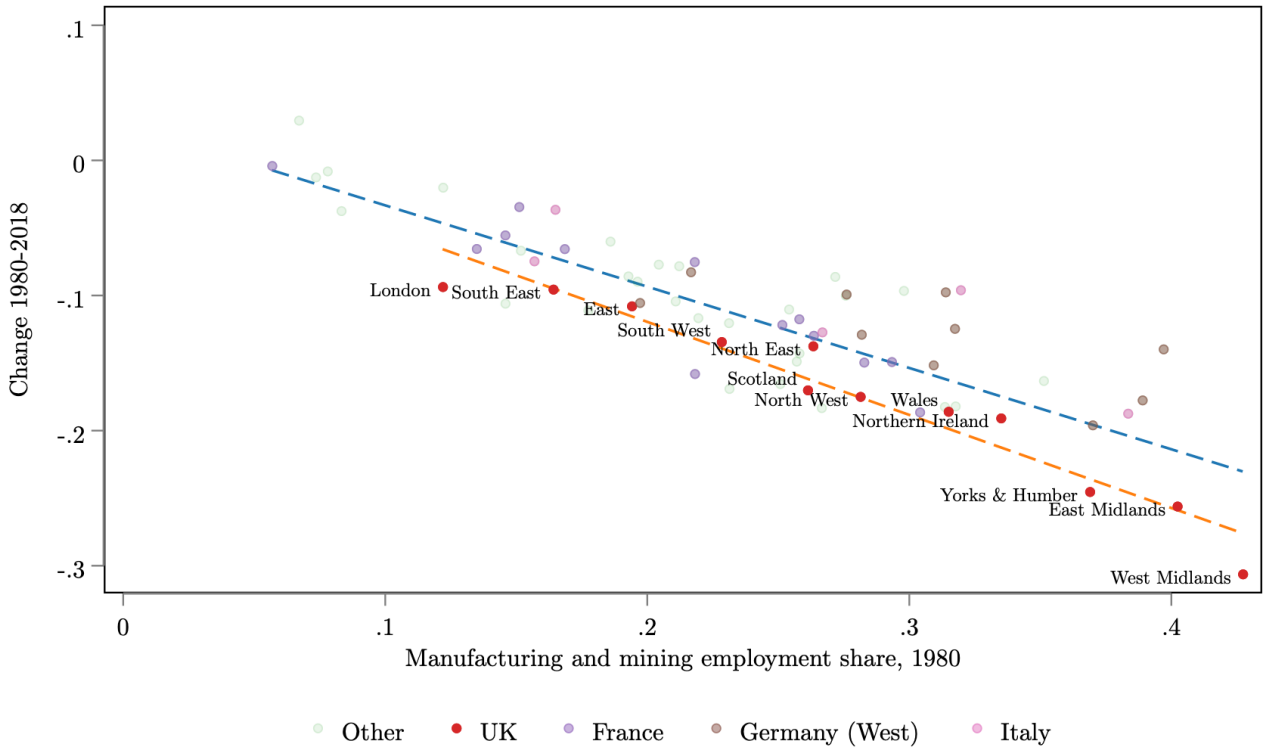


Figure 5: Change in range of GVA per worker, highest and lowest ITL2 regions, 1980–2019.

- The UK has the greatest range of regional productivity among its peers.
- Along with France, the UK's regional productivity is wide and getting wider.

The UK suffered severe deindustrialisation...

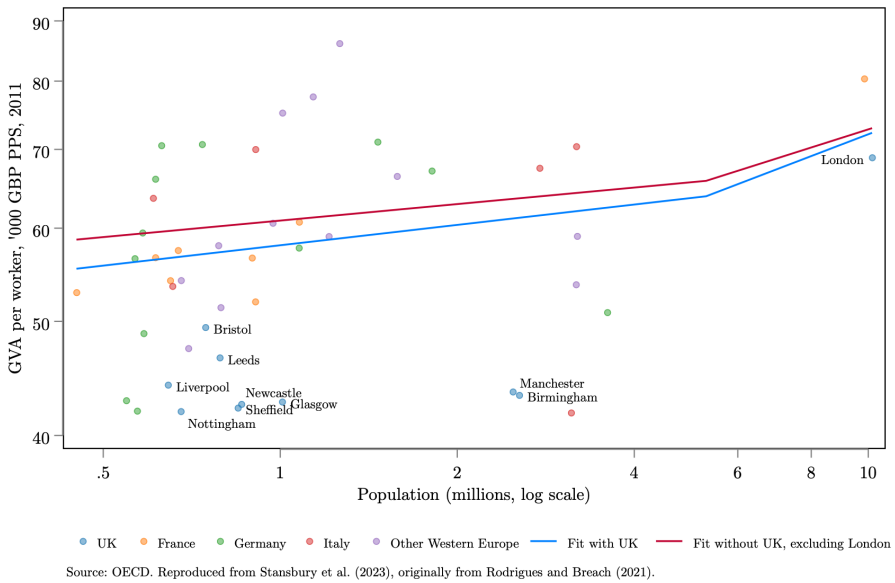


Source: ARDECO. Reproduced from Stansbury et al. (2023).
Blue denotes line of best fit across all regions; orange line denotes line of best fit for UK only. 'Other' includes NUTS1 regions in Austria, Belgium, Denmark, Finland, Greece, Ireland, Luxembourg, Netherlands, Norway, Portugal, Spain

Figure 6: Deindustrialisation in Western European regions, 1980-2018.

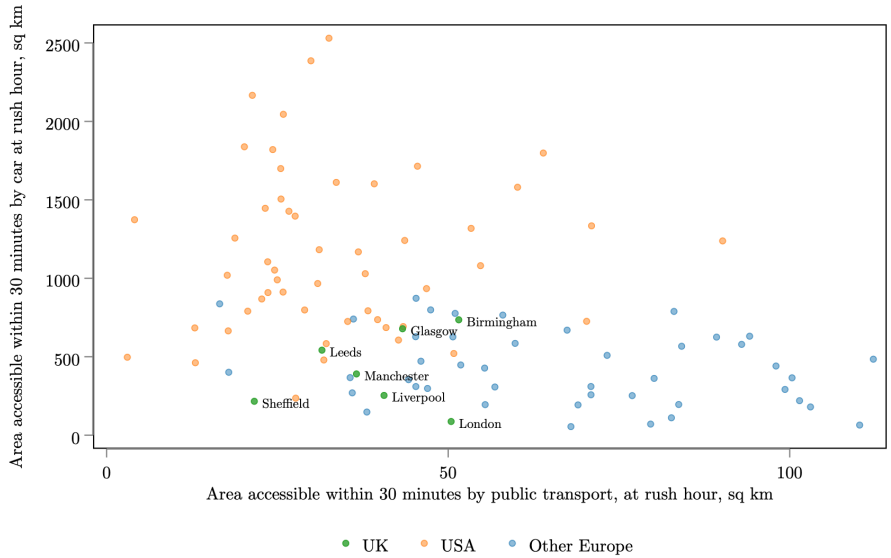
- The UK started with high rates of industrialisation and then experienced a precipitous decline in manufacturing employment shares.

. . . and the UK's cities significantly underperform their peers



Source: OECD. Reproduced from Stansbury et al. (2023), originally from Rodrigues and Breach (2021).

Figure 7: Productivity and city populations, Western Europe.



Source: OECD. Reproduced from Stansbury et al. (2023), originally from Conwell, Eckert, and Mobarak (2022). Esimates computed using Google Maps data with a start time of 08:30

Figure 8: Area accessible by road and public transport, UK, US and Western European cities.

- Explanations for regional divides today are also a function of agglomeration forces not operating as expected.
- Part of the explanation of this is the UK's poor transport infrastructure, which limits *effective* city size.

Against the backdrop of this challenge, industrial policy is back globally. . .

Figure 9: TSMC, Arizona.

- States, mostly driven by geopolitical concerns but also the energy transition and secular slow growth, are returning to industrial policy.

. . . and now represents a significant spending outlay. . .

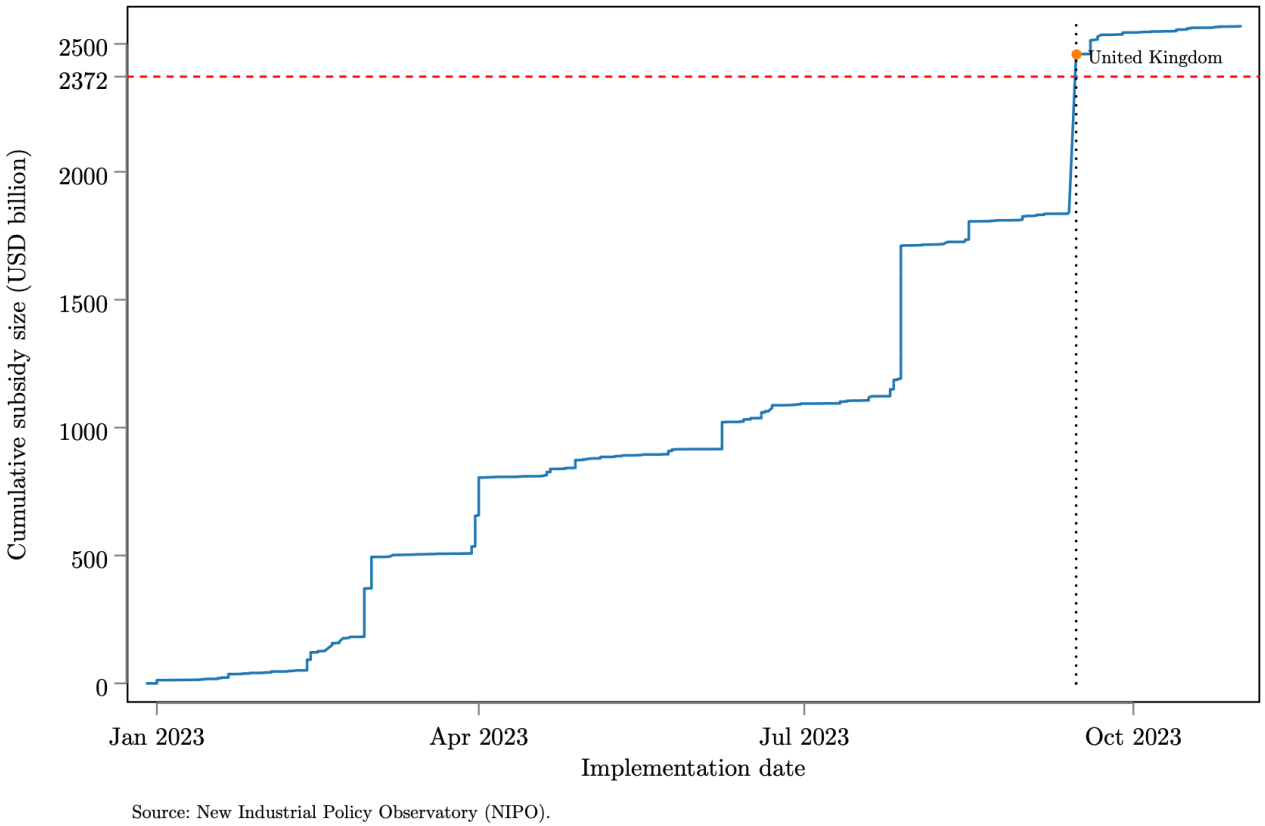


Figure 10: Industrial policy investment, 2023.

- In 2023, there was over $2 trillion of industrial policy interventions, about 2% of global output.

. . . but it hasn't always gone to plan in the UK. . .

Figure 11: The gigafactory that never was.

Figure 12: The steel works that still is.

- Since the 1980s, the UK has lacked an organised industrial policy.
- Recent attempts have been ad hoc and short-lived.
- Similar trends are observed in other advanced economies.

. . . but the UK's sub-national governance has changed recently and there is an opportunity to improve policy.

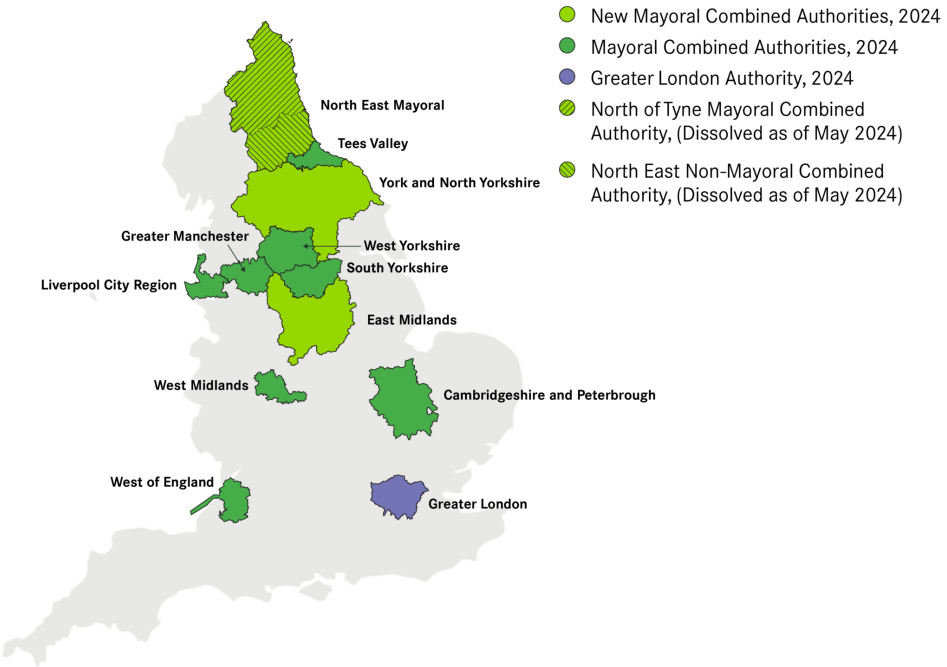


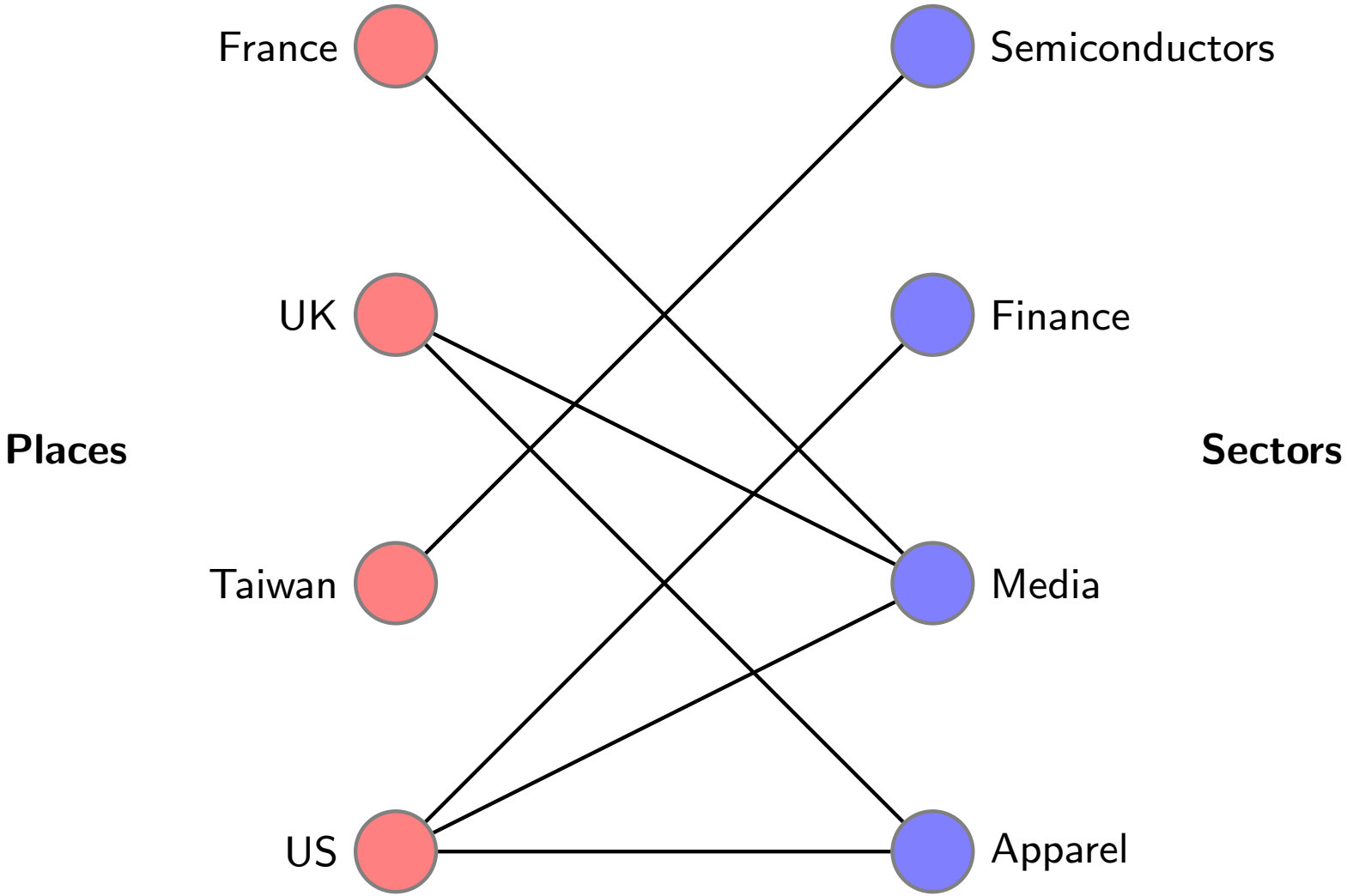
Figure 13: Metro Mayors and the Mayor of London, May 2024.

- A metro mayor is the directly elected leader of an area, often a city.
- Groups of smaller local authorities negotiate a 'devolution deal' with the central government to give metro mayors executive powers and funding.
- They can make strategic decisions over a range of policy areas including skills, businesses support, transport, and in some cases crime and health.

Economic complexity provides a toolkit to think about these problems

- Industrial policy needs to start with some model of the economy.
- It is difficult to observe what is actually needed to produce advanced outputs ('TFP is a residual').
- But we know two things:
  1. That harder things are rarer (think semiconductors and gas stations)
  2. Trivially, doing something means you have the 'capabilities' to do it (and are likely to do 'related things')
- Economic complexity builds a network view of an economy by observing interactions between places and sectors, i.e., what places do what.
- Key sources: Hidalgo and Hausmann (2009), seminal works on economic complexity. Now a big literature covering most econ sub-fields including macro, labour, finance.
- Recent move to apply the methods sub-nationally, e.g., China (Gao and Zhou 2018) and the US (Fritz and Manduca 2021).

The essential idea is to map places to what they do



Conceptually, we take a snapshot of who does what, and where. . .

- Set of places, $C = \{1, 2, \ldots, N_c\}$ and set of activities (industries), $P = \{1, 2, \ldots, N_p\}$
- Revealed Comparative Advantage (RCA) or Location Quotient (LQ):

RCA or LQ

$$R_{cp} = \frac{X_{cp} \times X}{X_c \times X_p}$$

Conceptually, we take a snapshot of who does what, and where. . .

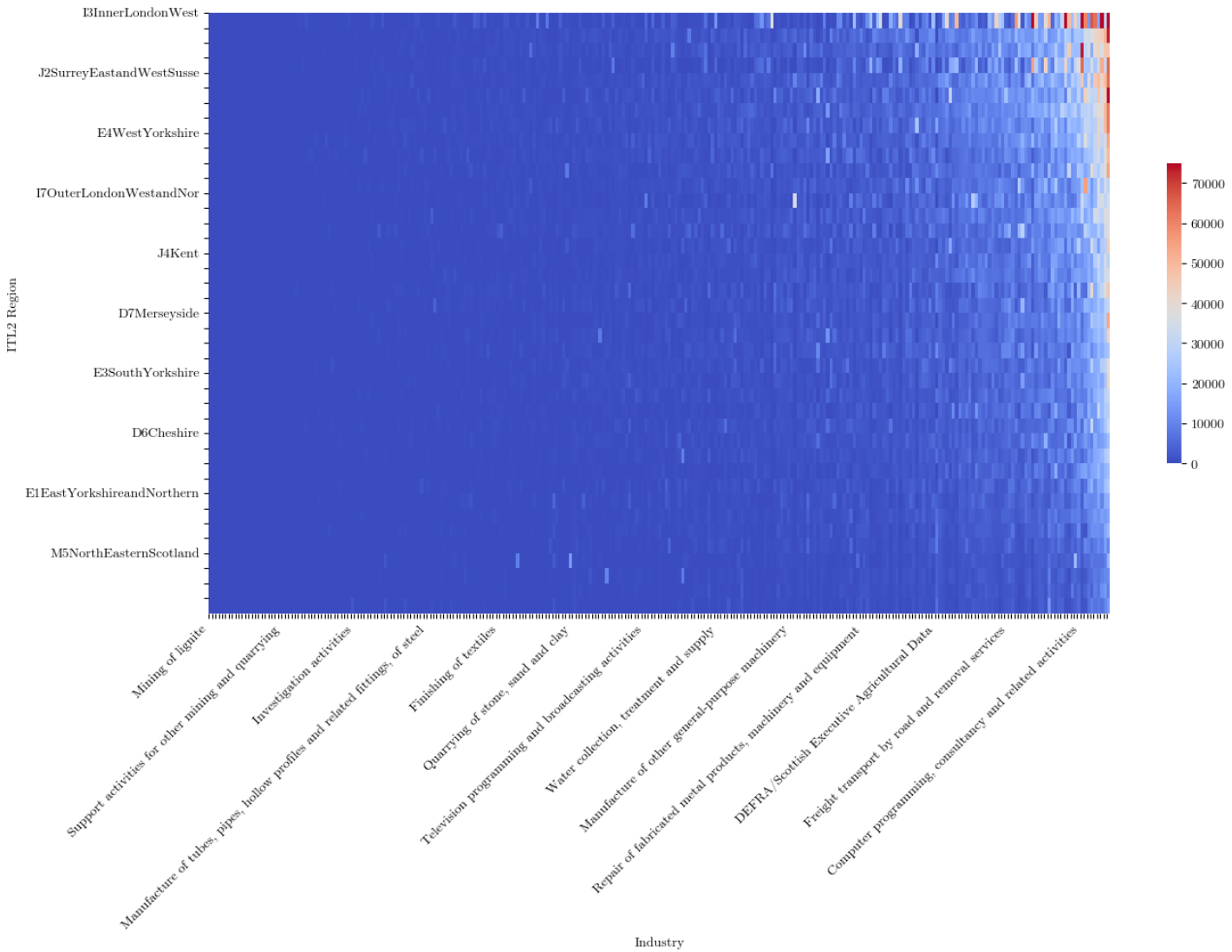


Figure 14: The X matrix shows sectors of regional employment strength.

. . . then we work out who produces competitively. . .

Presence Matrix M

$$M_{cp} = \begin{cases} 1 & \text{if } R_{cp} \geq 1 \\ 0 & \text{otherwise} \end{cases}$$

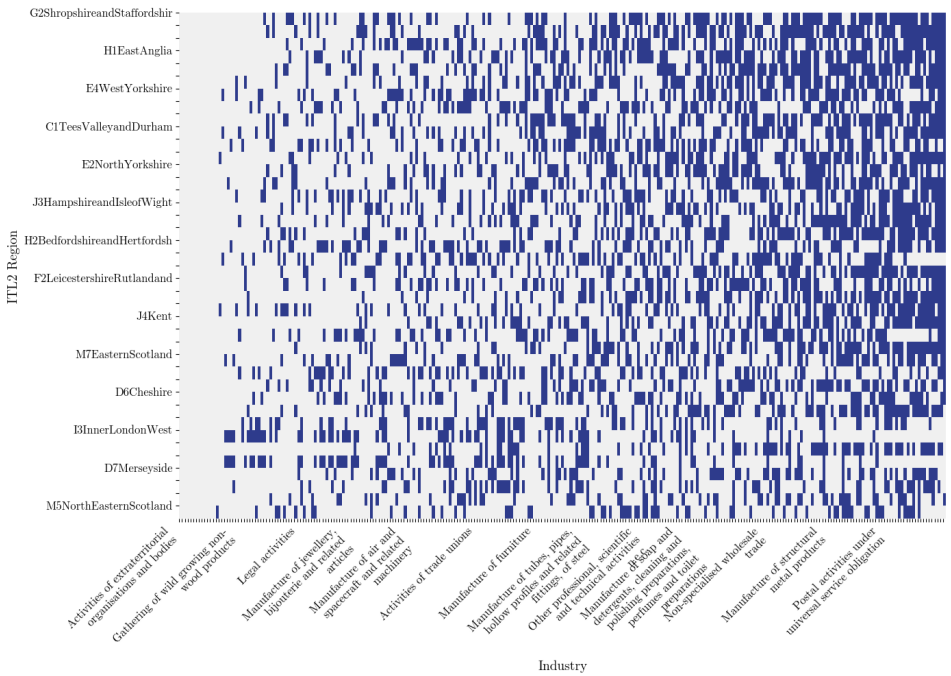


Figure 15: The M matrix shows the revealed comparative advantage of regions in sectors.

. . . and from this we get a sense of how scarce success in the sector is (ubiquity) and how many scarce things a place does (diversity)

Diversity D and Ubiquity U

Diversity (D) and Ubiquity (U):

$$D_c = \sum_p M_{cp}, \quad U_p = \sum_c M_{cp}$$

Diagonal Matrices

Construction of diagonal matrices:

$$D^{-1} = \begin{bmatrix} \frac{1}{d_1} & 0 & \dots & 0 \\ 0 & \frac{1}{d_2} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \frac{1}{d_n} \end{bmatrix}, \quad U^{-1} = \begin{bmatrix} \frac{1}{u_1} & 0 & \dots & 0 \\ 0 & \frac{1}{u_2} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \frac{1}{u_m} \end{bmatrix}$$

Weight what you're good at by these measures of scarcity

Construction of $\widetilde{M}$

Construction of $\widetilde{M}$:

$$\widetilde{M} = D^{-1} M U^{-1} M'$$

Economic Complexity Index (ECI)

Economic Complexity Index (ECI):

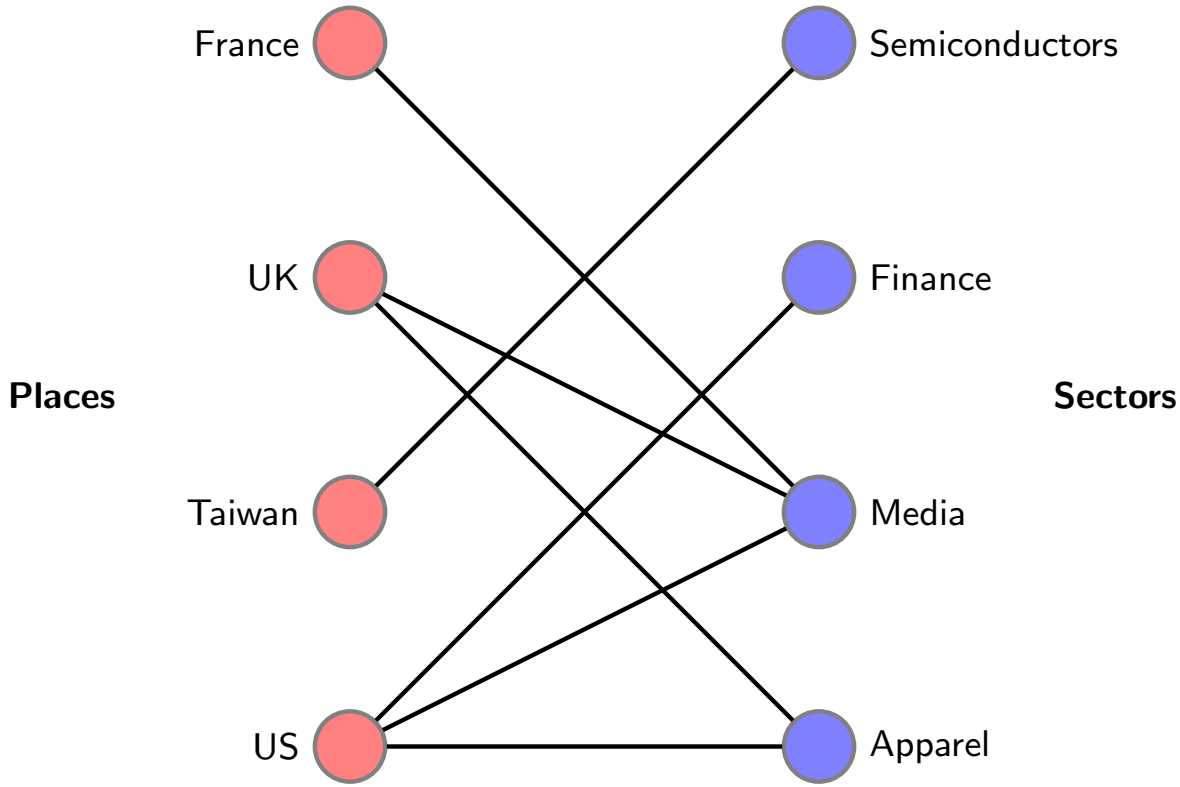
$$ECI = \mathbf{v}_2(\widetilde{M})$$

- Reflects how regions share industrial strengths, adjusted for each industry's ubiquity.

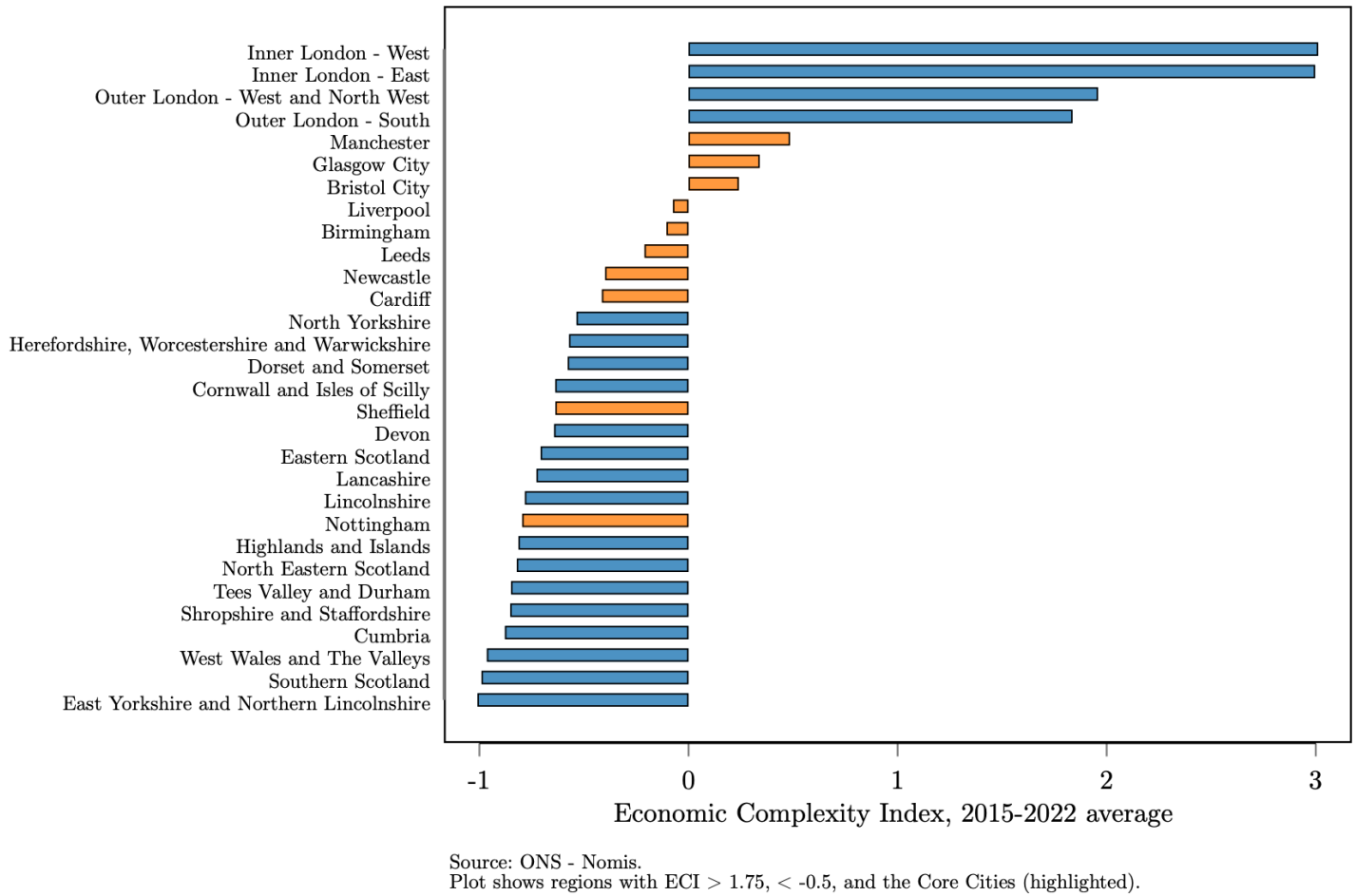
All we've done is formalise the idea from the diagram

Economic Complexity Matrix

$$\widetilde{M} = D^{-1}MU^{-1}M'$$



Economic complexity in London outstrips the regions and other cities



Source: ONS - Nomis.
Plot shows regions with ECI > 1.75, < -0.5, and the Core Cities (highlighted).

Figure 16: Employment-based ECI, by ITL2 region, 2015-2022 average.

Economic complexity clusters in London and the South East

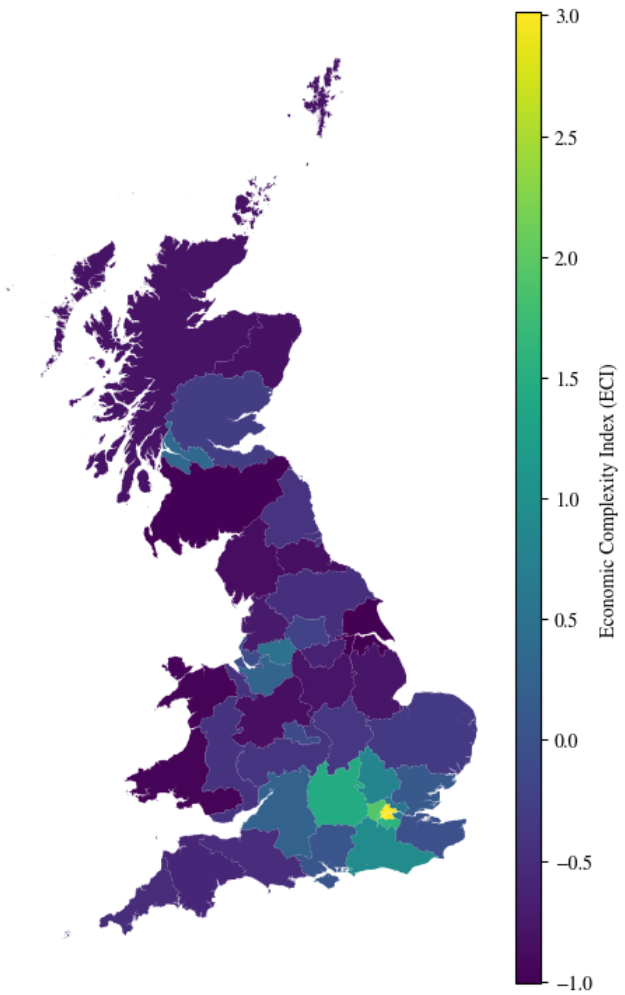


Figure 17: Employment-based ECI, by ITL2 region, 2015-2022 average.

Complexity is driven by high-value services, done well in a few places

- The most complex sectors are almost all knowledge-intensive services.
- But the most complex places aren't doing more things well than less complex places.

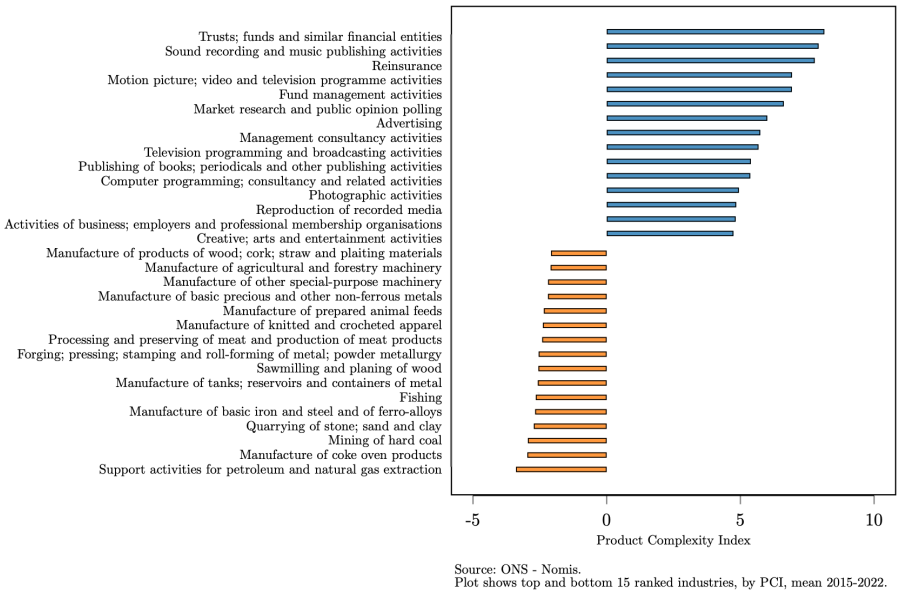


Figure 18: Employment-based PCI, by industry.

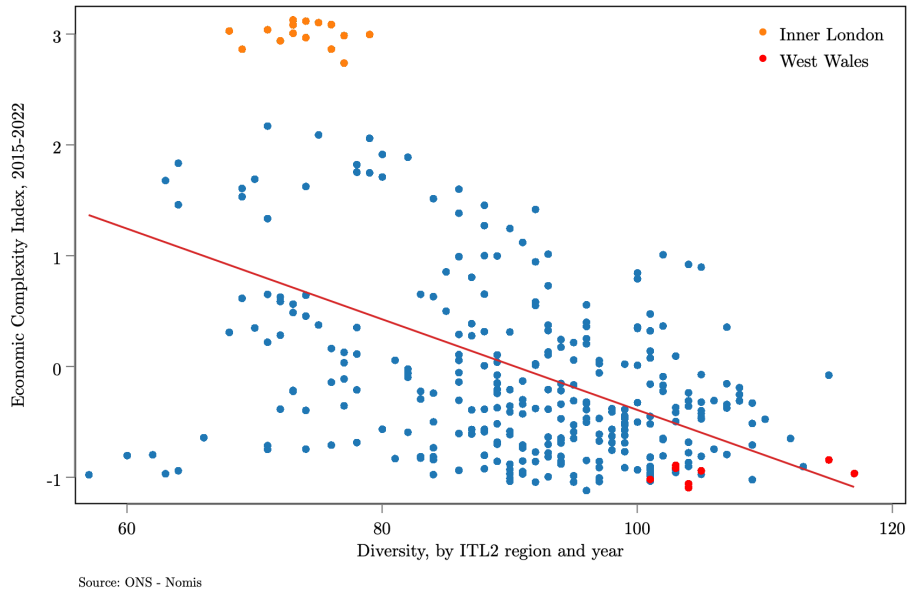
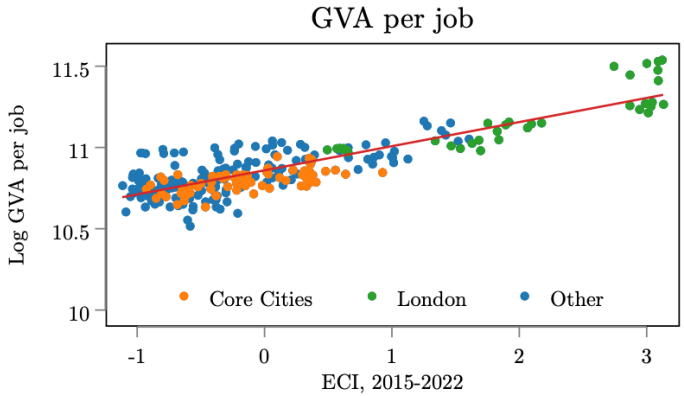
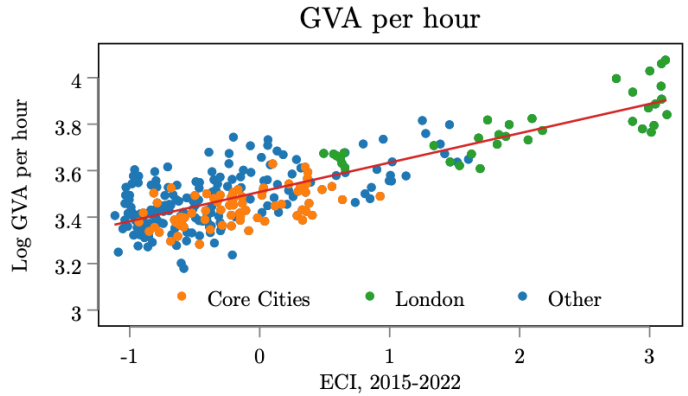


Figure 19: ECI and sectoral diversity, by ITL2 region, 2015-2022.

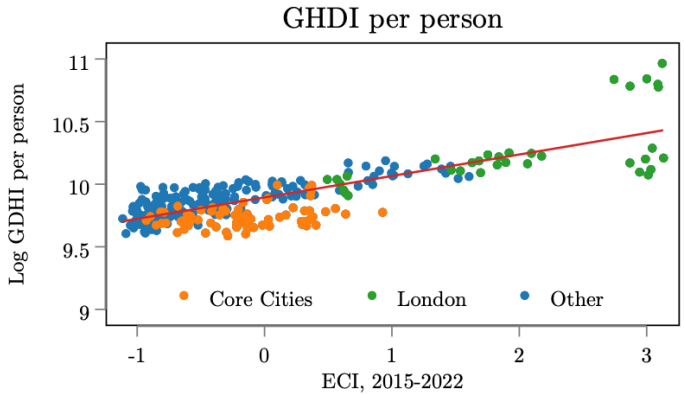
Complexity performs well predicting sub-national outcomes



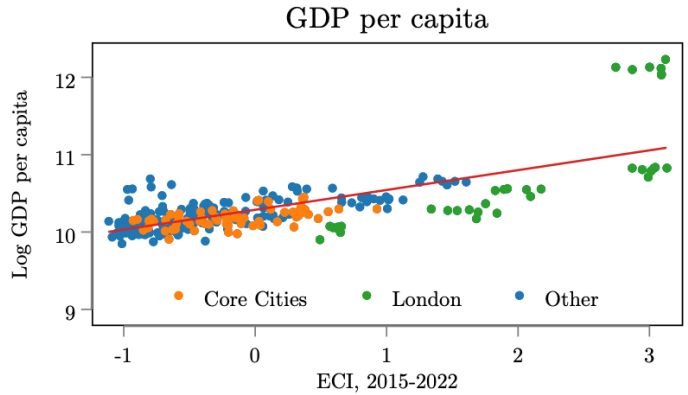
Source: ONS. Each observation is at year-ITL2 level.



Source: ONS. Each observation is at year-ITL2 level.



Source: ONS. Each observation is at year-ITL2 level.



Source: ONS and HMRC. Each observation is at year-ITL2 level.

Figure 20: Employment-based ECI and key economic outcomes, 2015-2022.

Cross-section Regression Results: Economic Complexity and Economic Output

Cross-section Model

$$y_i = \beta_0 + \beta_1 \text{ECI}_i^{\text{emp}} + \beta_2 \text{ECI}_i^{\text{exp}} + \boldsymbol{\beta}_3^T \mathbf{X}_i + \epsilon_i$$

	ln GVA per hour			ln GDP per capita		
VARIABLES	(1)	(3)	(5)	(7)	(9)	(11)
ECI Emp	0.109***	0.0338***	0.0995***	0.196***	0.0176	0.188***
	(0.00638)	(0.00755)	(0.0117)	(0.0287)	(0.0260)	(0.0567)
ECI Exports			0.0263***			−0.0394
			(0.00990)			(0.0285)
ln GFCF	0.0511***	0.0635***	0.0304	0.163***	0.177***	0.175***
	(0.0133)	(0.0103)	(0.0226)	(0.0315)	(0.0320)	(0.0596)
Sh Tertiary		0.0101***			0.0272***	
		(0.000732)			(0.00352)	
Constant	3.039***	2.482***	3.282***	8.831***	7.575***	8.697***
	(0.119)	(0.101)	(0.205)	(0.280)	(0.384)	(0.534)
Observations	240	195	80	240	195	80
R^2 **adjusted**	0.694	0.831	0.750	0.567	0.747	0.545

Note: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Robust standard errors in parentheses.

Panel Regression Results: Economic Complexity and Economic Output

Panel Models

Fixed effects:

$$y_{it} = \alpha_i + \beta_1 \text{ECI}_{it}^{\text{emp}} + \beta_2 \text{ECI}_{it}^{\text{exp}} + \boldsymbol{\beta}_3^T \mathbf{X}_{it} + \gamma_t + \epsilon_{it}$$

Random effects:

$$y_{it} = \gamma + \beta_1 \text{ECI}_{it}^{\text{emp}} + \beta_2 \text{ECI}_{it}^{\text{exp}} + \boldsymbol{\beta}_3^T \mathbf{X}_{it} + \upsilon_i + \epsilon_{it},$$

	ln GVA per hour			ln GDP per capita		
VARIABLES	(1)	(4)	(5)	(7)	(10)	(11)
ECI Emp	0.0776***	0.119***		0.0940***	0.215***	
	(0.0112)	(0.00659)		(0.0363)	(0.0257)	
ECI Exports			0.0519***			0.0255
			(0.0109)			(0.0214)
ln **GFCF**	0.100***	0.0535***	0.153***	0.109***	0.246***	0.505****
	(0.0210)	(0.0125)	(0.0309)	(0.0292)	(0.0437)	(0.128)
Constant	2.601***	3.005***	2.166***	9.312***	8.058***	5.697***
	(0.190)	(0.112)	(0.279)	(0.245)	(0.387)	(1.133)
Observations	240	198	66	240	198	66
Urban FE	NO	YES	YES	NO	YES	YES
R^2 **within**	0.064			0.0418		
R^2 **between**	0.740			0.582		
R^2 **overall**	0.670			0.568		
R^2 **adjusted**		0.788	0.592		0.662	0.501

Note: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Robust standard errors in parentheses.

Applying economic complexity to industrial policy

- We now know that economic complexity provides predictive insights into economic outcomes at the sub-national level.
- UK industrial policy has historically lacked coordination and needs quantitative tools to inform its future path.
- Economic complexity measures, by illustrating geographic and industrial variations, give us a tool to target interventions.

First, we compute the 'proximity' pairs of sectors...

Proximity Matrix ϕ

Define the proximity matrix, ϕ, capturing the likelihood of two industries co-existing in a region:

$$\phi_{pq} = \min\left(\frac{\sum_c M_{cp}M_{cq}}{\sum_c M_{cp}}, \frac{\sum_c M_{cp}M_{cq}}{\sum_c M_{cq}}\right)$$

- **Binary Co-occurrence**: The matrix elements ϕ_{pq} are calculated by determining where two industries p and q co-exist across regions, using the presence matrix M.
- **Normalised Ratios**: This sum is normalised by the total presence of each industry across all regions, creating two ratios that reflect the proportion of co-existence relative to each industry's presence, i.e., *where do p and q co-exist, as a share of all the places where p or q exist.*
- **Minimum Value Selection**: Take the minimum to avoid overestimating the connection. Think biotech and agriculture, ϕ_{AB}. The likelihood of finding biotech (B) in regions where agriculture (A) exists will be higher than the other way around.

A higher value of ϕ_{pq} suggests that these industries often co-locate, indicating potential synergies or complementary activities between them.

. . . which can then be used to compute the 'density' of sectors around a place

Density Measure ω_{cq}

$$\omega_{cq} = \frac{\sum_p M_{cp}\phi_{pq}}{\sum_p \phi_{pq}}$$

- The density of industry q in region c is a ratio that reflects how integrated q would be within the existing industrial structure of c.
- We count the number of industries that exist in places (M_{cp}), and then weight it by how far the existing industry is from the industry we're interested in (ϕpq).
- A higher density value implies that q is closely connected to several key industries in c, suggesting that q could potentially thrive or be relevant in that regional market.
- Imagine renewable energy (R) and Green Valley (G), which is known for its strong agricultural sector (A) and burgeoning technology sector (T).
- The density ω_{RG} calculates the average weighted presence of industries (A and T) around renewable energy, considering their proximity to renewable energy.

These relationships allow us to plot sectors as a network

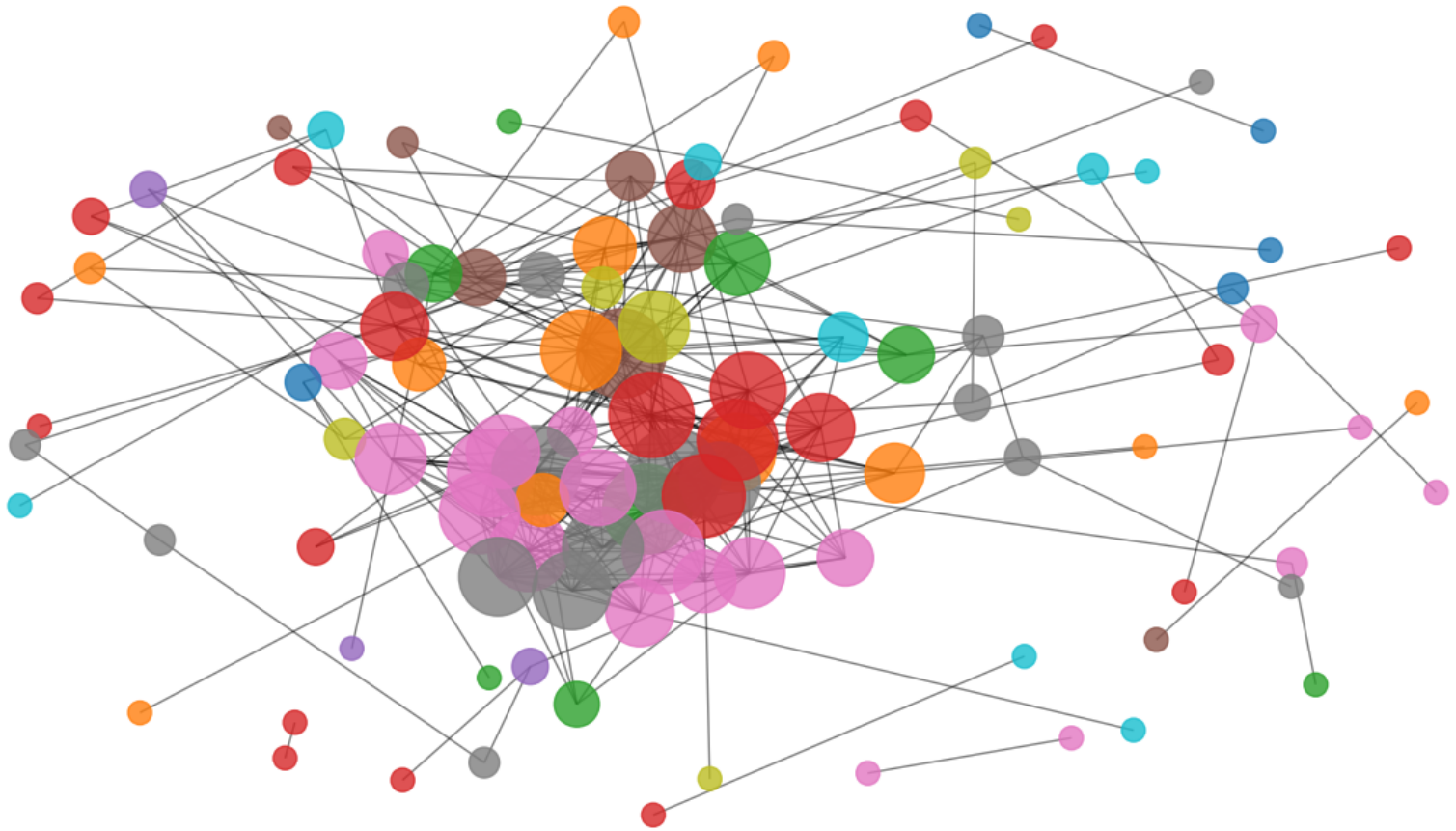
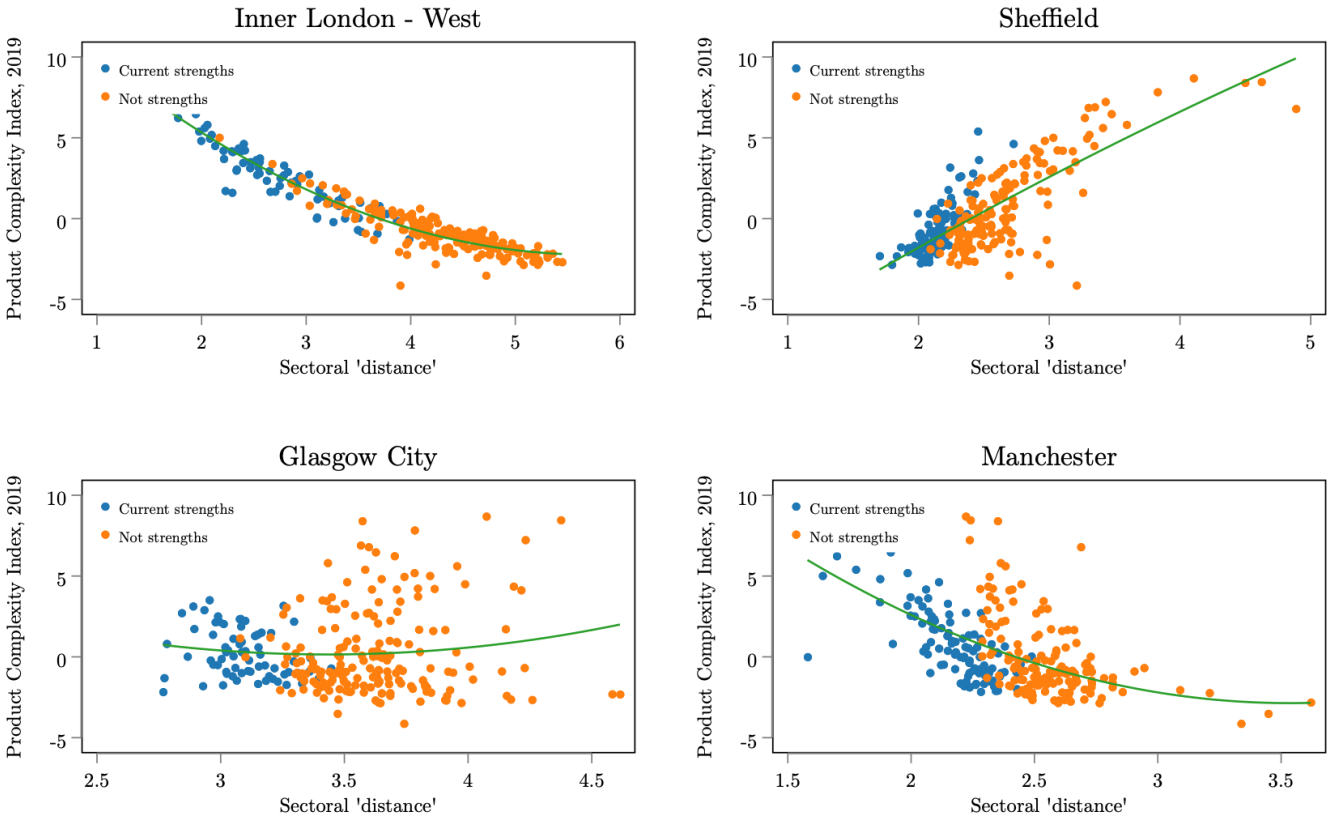


Figure 21: Network plot of sectors and proximity.

Nodes=sectors (larger=more connections), edges=ϕ. Colour by industry grouping.

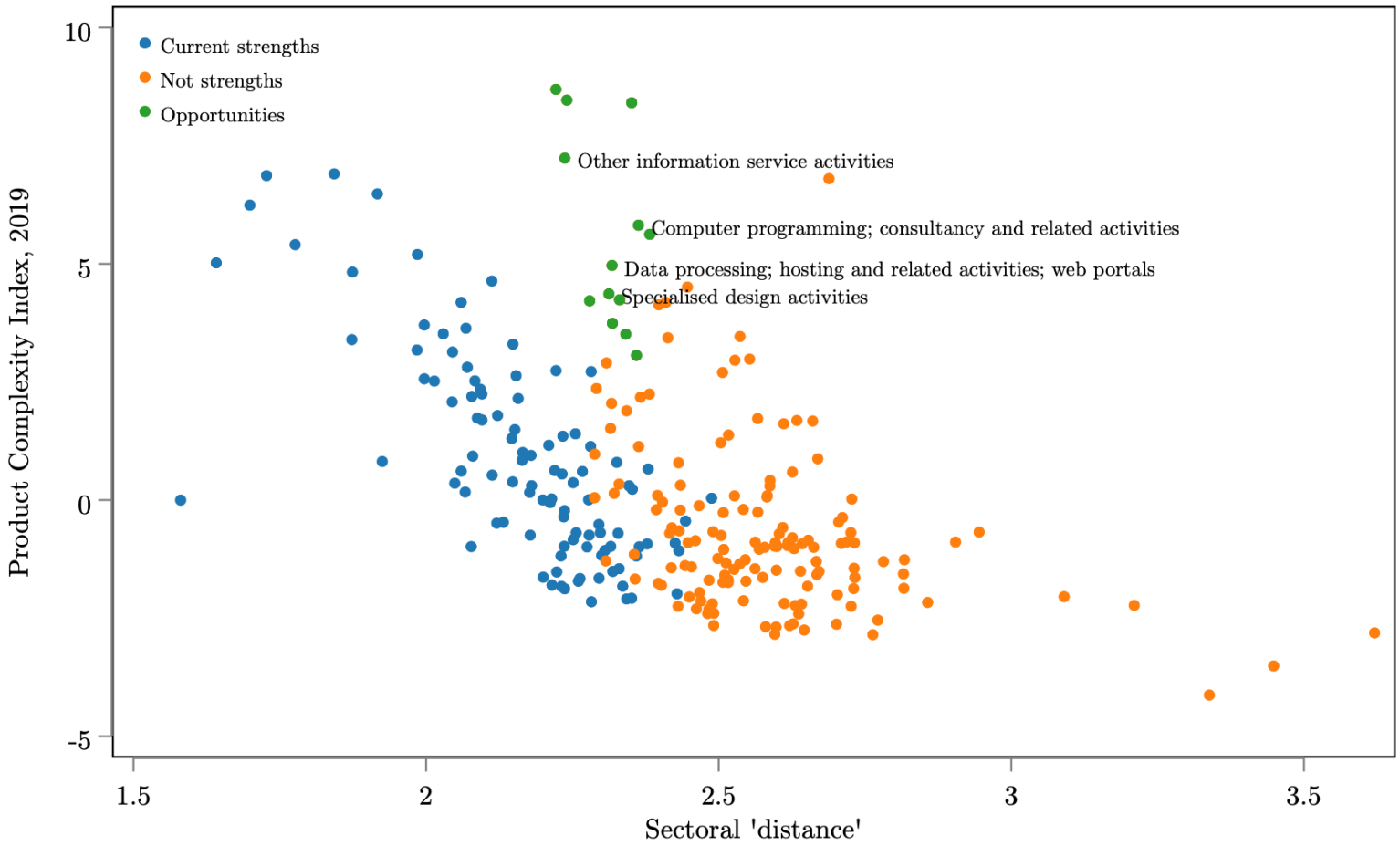
Plotting sectoral complexity and 'distance' can help us to understand economic structure



Source: ONS - Nomis. Strengths are sectors where the place has an RCA > 1.

Figure 22: Comparing PCI and sectoral 'distances', UK cities, 2019.

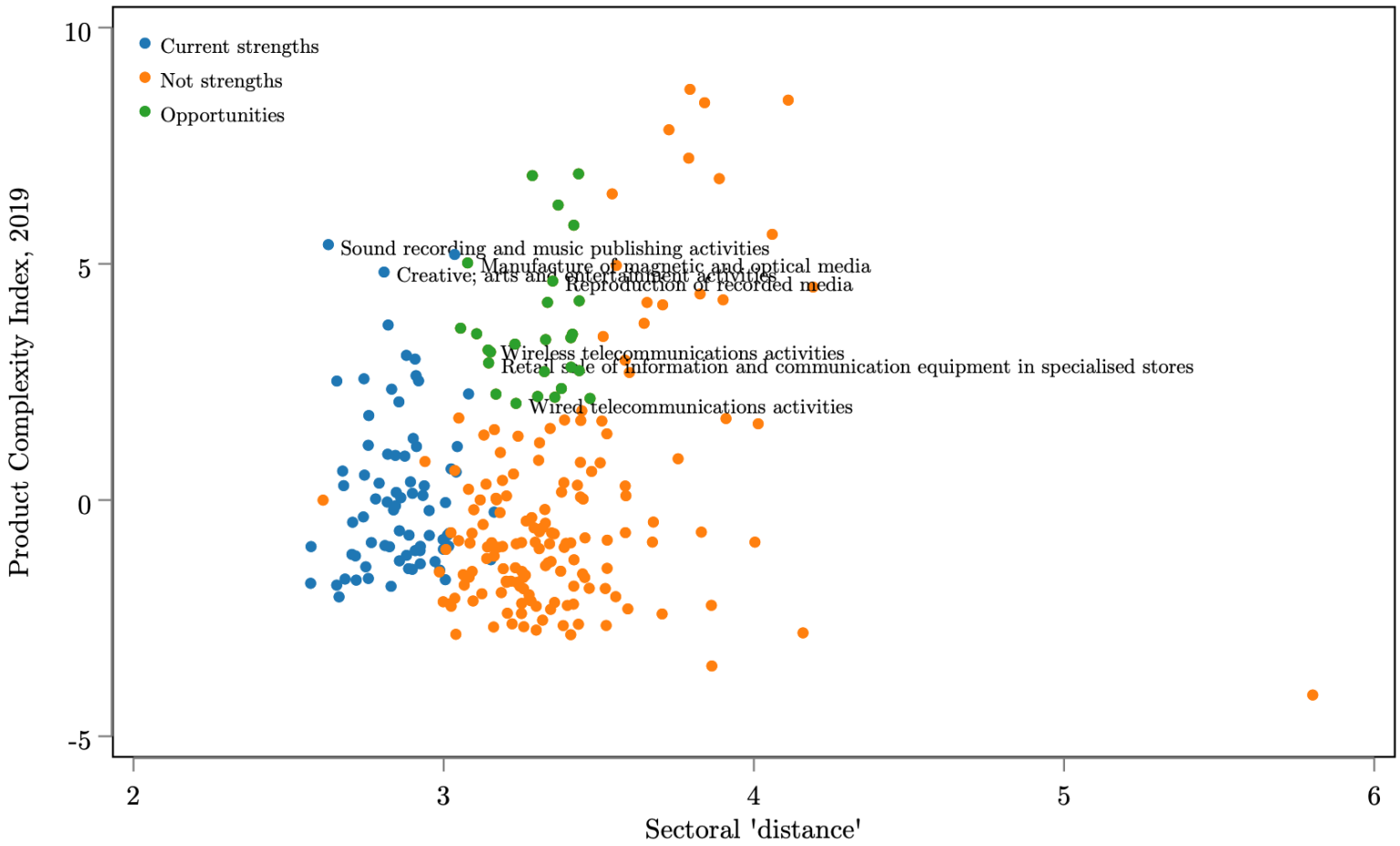
We can then use this to inform sectors for industrial strategy



Source: ONS - Nomis. Distance = 1/Density.
Opportunities are sectors with PCI > 3 and Distance < 50 percentile of area-year distances but RCA < 1

Figure 23: PCI and sectoral distance, Manchester, 2019.

Because of the complexity framework, sectors build on existing strengths



Source: ONS - Nomis. Distance = 1/Density.
Opportunities are sectors with PCI > 2 and Distance < 3.5 but RCA < 1

Figure 24: PCI and sectoral distance, Liverpool, 2019.

The Complexity Outlook Index (COI) gives a holistic sense of the prospects of a place

Complexity Outlook Index COI_c

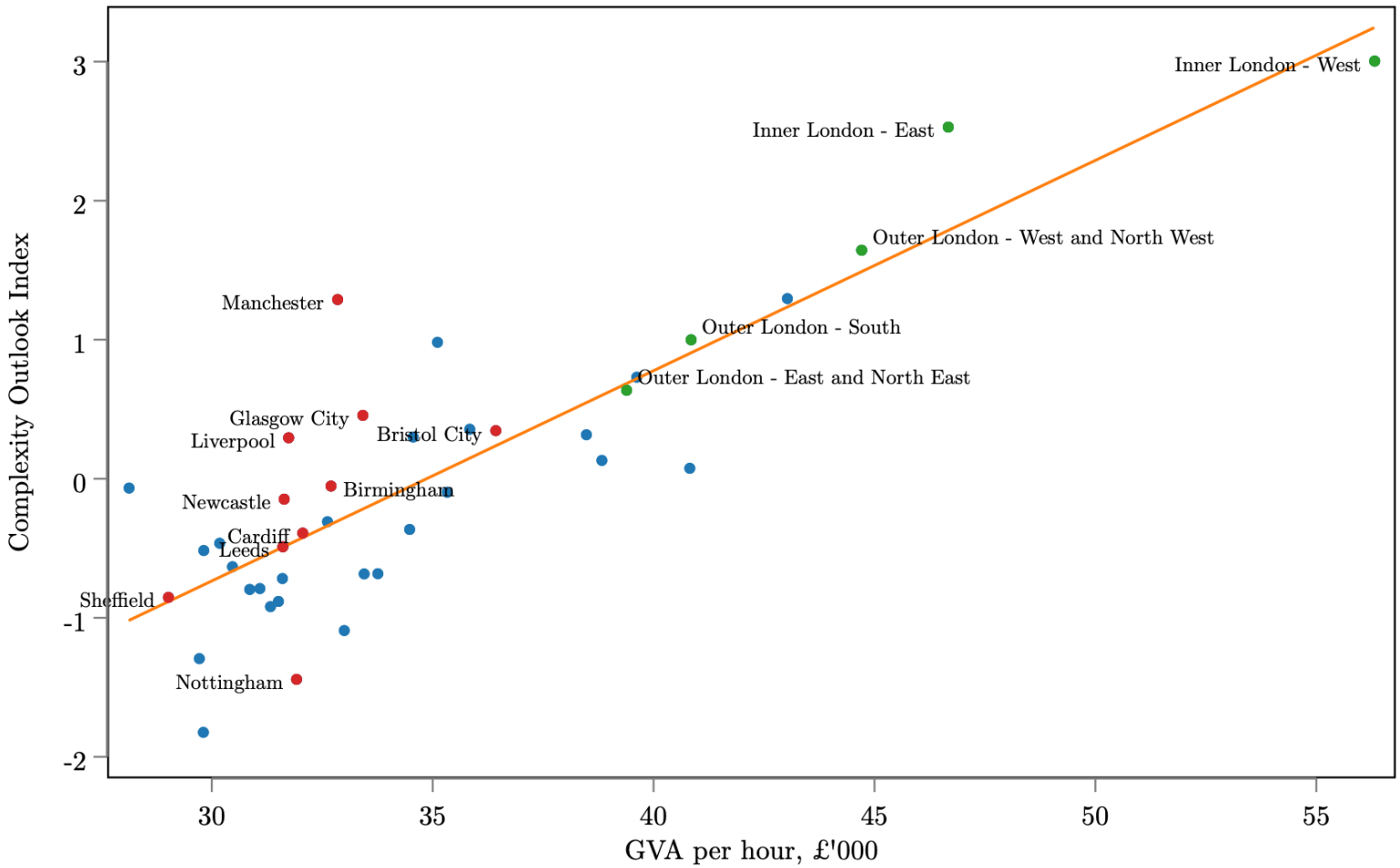
The COI measures the potential of a place to move into more complex sectors based on its current industrial structure:

$$\mathrm{COI}_c = \sum_p (1 - d_{cp})(1 - M_{cp})\,\mathrm{PCI}_p,$$

- **Closeness:** $1 - d_{cp}$ indicates the proximity of current sectors to more complex ones.
- **Weights:** Each potential new sector is weighted by its complexity (PCI_p).
- **Exclusion Principle:** $1 - M_{cp}$ ensures the sum only includes sectors not currently present.

Higher COI suggests a place has high potential for industrial upgrading, especially into sectors that are near but not yet present.

The Complexity Outlook Index gives us another way to think about the allocation of industrial policy resources



Source: ONS - Nomis. London and Core Cities highlighted.

Figure 25: GVA per hour and Complexity Outlook Index, Core Cities and London, 2019.

The Opportunity Outlook Gain also gives us insights about where to target industrial policy

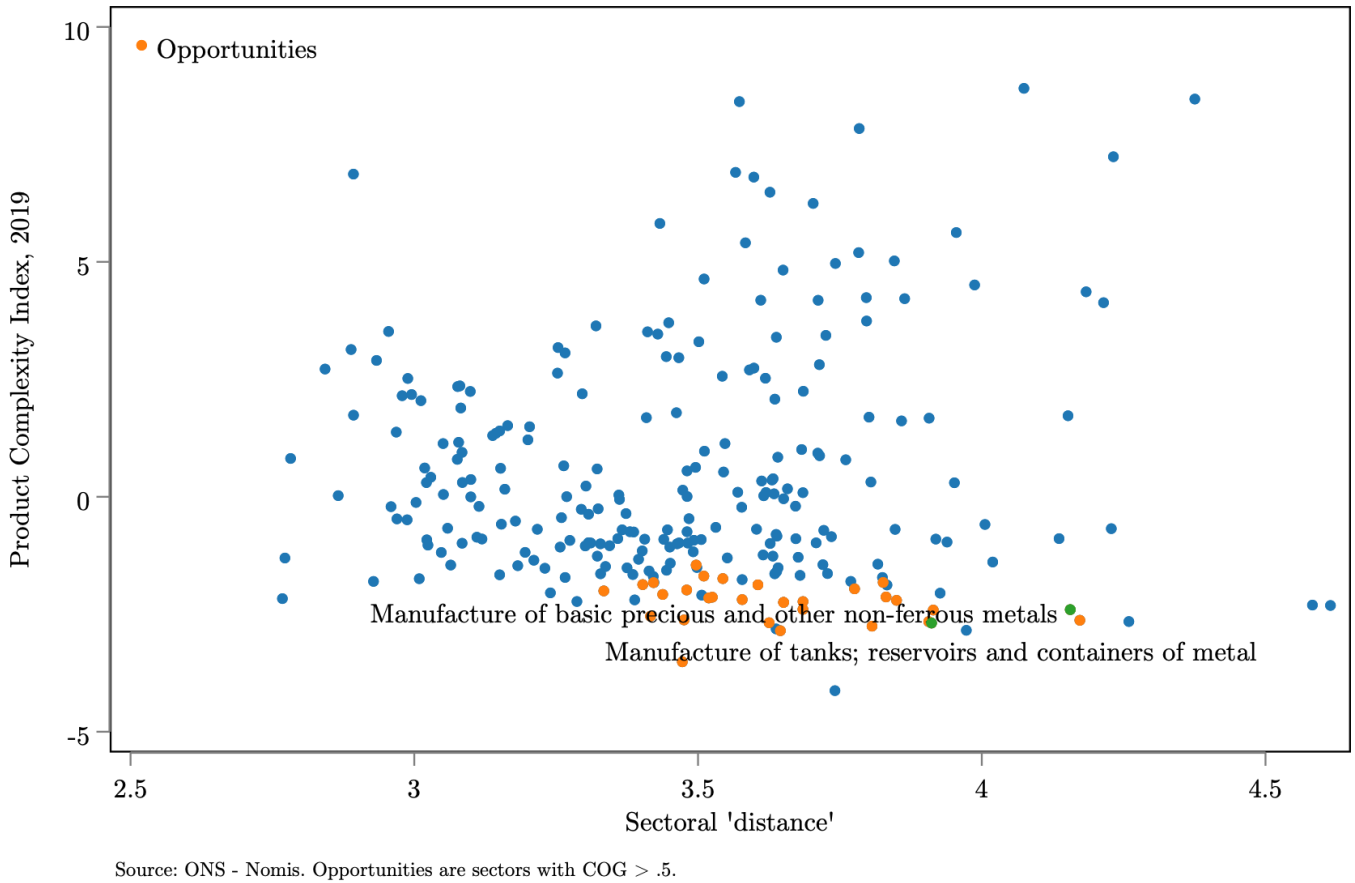


Figure 26: PCI and sectoral distance, with Opportunity Outlook Gain, Glasgow, 2019.

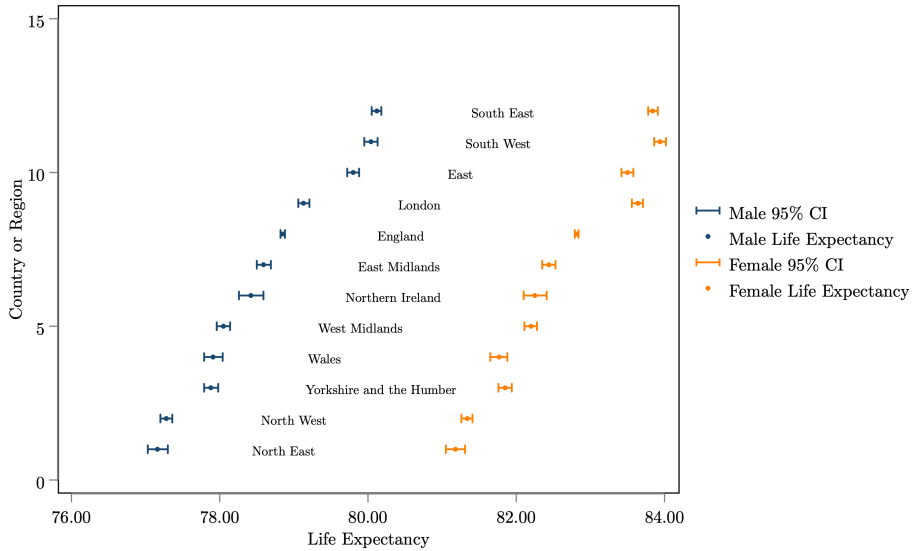
Where does this leave us

1. The UK has some of the worst spatial disparities of any advanced economy.
2. Industrial policy is back in mainstream policy, but currently lacks solid theoretical frameworks relevant to policy.
3. Economic complexity is a useful set of tools that can be used to address these challenges.
4. The measures predict important economic outcomes, relevant to improving living standards across the regions of the UK.
5. Economic complexity can be applied to develop a sectorally-led industrial policy, that targets sectors related to the existing industrial strengths of a place.
6. No framework is perfect, and it will need to be integrated with a range of social and political economy considerations (e.g., planning system in the UK context) but it gives policymakers a quantitative framework they can build off.

The stakes are high. Without action, we lose the potential of millions.

"A decade of under-performance would significantly harm living standards and could leave the UK falling behind other leading European economies. The recent experience of Italy shows that once relative decline sets in, it can persist for a long time. The UK has already fallen behind Germany of late: on the eve of the financial crisis, GDP per capita in the UK was just 6 per cent lower than in Germany, but after a large downturn and slower recovery this gap had risen to 12 per cent by 2019. If this relative decline continues at the same pace in the 2020s, then the UK will end this decade closer to Italy than Germany when it comes to economic performance."

— **Resolution Foundation**, *The UK's Decisive Decade: The Launch Report of The Economy 2030 Inquiry*



Source: ONS. Plot shows life expectancy at birth (by sex) in 2020 to 2022 for England, Northern Ireland, Wales, and English regions.

Figure 27: Life expectancy at birth, UK ITL1 regions and countries, 2020-2022.

Thank you.

Thank you class of 2024 for a wonderful two years. Here's to the future. Good luck.