Speech

Is All Economics Local?

Speech given by

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It is wonderful to be here at the University of Sheffield, my *alma mater*, to give the SPERI Annual Lecture. I have been a great admirer of SPERI's work over the years. It has played an important role in shaping the conversation about public policy, economically and socially, locally and nationally. My topic today echoes many of the themes SPERI has championed – the role of local perspectives and policies in better understanding the economy and in shaping a better society.

Tip O'Neill, the former Speaker of the United States House of Representatives, famously said "all politics is local". Those words probably apply to politics everywhere. They have also probably been true at every point in history. But at this particular point in history, with local or national identities becoming an increasingly potent force shaping our economies and societies, those words have a particular resonance.

That set me thinking. Does the O'Neill hypothesis hold for our economies too? Is all *economics* local? Are our economies better understood as a nation-state solid or as a set of loosely-linked local clusters? Might this have implications for how we map, model and manage the economy? And might it even have implications for central banks, despite their policies operating nationally rather than locally?

I want to explore these questions, tentatively and provisionally, first by drawing some simple maps of the economy at different spatial resolutions. These maps provide some insight into how "local" economies really are. How large are differences *between*-region? How do they compare with differences *within*-region? And what do we know about *flows* of factors, including people, between and within regions?

This local lens poses some interesting questions about how the economy should be modelled. Existing models of the macro-economy operate at a high level of aggregation. When is this telescopic lens on the economy the most useful one? When might a microscopic, or local, lens offer additional insights? And how, practically, can those microscopic perspectives be pieced together to give a macroscopic overview?

When it comes to managing the economy, this has been fertile ground for policy debate recently. Several reports have made the case for rethinking local economic policies, including Michael Jacobs' work as part of the IPPR Commission on Economic Justice.[1] The Government has put "place" centre-stage in its own policy agenda.[2] I discuss ways in which analytical techniques and data might help in shaping those policy choices.

Some areas of public policy can only operate at the national rather than local level, such as monetary policy. Even then, however, a local perspective can be important for better understanding the economic issues people face and for building understanding and trust among those people. That is why the Bank of England has recently augmented its own local initiatives, as I will discuss. Other central banks are following suit.

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[1] IPPR Commission on Economic Justice (2018). See also Collier (2018).
[2] Department for Business, Energy and Industrial Strategy (2017).

In his recent book, Raghu Rajan blames neglect of the *Third Pillar* of society – community – relative to the market and the state (the first two pillars) for rising societal disconnection and mistrust.[3] Rajan is right. Economic policymakers, including central banks, have a pivotal role to play in resurrecting that Third Pillar, in making economic policy local, to better support our economies and societies. Here is how.

Mapping the Economy

Let me begin with some simple mapping of the economy. The most widely-used metric of economic success is Gross Domestic Product (GDP).[4] In simple terms, this measures how much the average person has available to spend on the good things in life. If asked, most people would say this is a decent, if partial, proxy for their overall economic health, even if they express bafflement at the concept of GDP.

Aggregate GDP is far from being the only possible proxy for economic health. The lived experience of most people depends on more than their income. A rich strand of literature has developed alternative measures of people's well-being. As well as economic and financial health, these measures include physical and mental health, their families, friends and communities.[5] This work tells us that people's sense of well-being, if not their GDP, is shaped by local factors, underpinned by the Third Pillar.

Another reason why aggregate GDP may not chime with most people's lived experience is because, by definition, most people are not "average". Economists use the idea of the average or representative agent as a convenient shortcut. But that agent is a fiction. People's lived experiences often differ very materially, even within a single country or region – spatially, socially and financially. For most people's everyday lives and everyday decisions, *all* economics is local.

These imperfections in GDP are well-understood. They certainly do not fatally undermine its usefulness as a means of keeping economic score. They do, however, suggest it can usefully be complemented by looking at the economy through different lenses. One of those different lenses comes from mapping the economy bottom-up, rather than top-down, aggregating microscopic experiences into a macroscopic view.

In medicine, we use a variety of different tools, at different resolutions, to diagnose problems and when prescribing solutions: thermometers, blood pressure monitors, X-rays, CT scans, ultrasound and blood tests. Rarely does one of these measures provide all of the diagnostic answers. Using them in combination can, however, help reach robust clinical conclusions. And that "micro-to-macro" approach is commonplace when understanding other complex adaptive systems like the body, natural, physical and social.

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[3] Rajan (2019).
[4] Coyle (2014).
[5] For example, Helliwell, Layard and Sachs (2019), Ngamaba (2017) and Commission on the Measurement of Economic Performance and Social Progress.

Like our bodies, the economy is also a complex, adaptive system. As in medicine, it can be measured using different tools at different resolutions. There are various metrics of societal health, in addition to GDP. For example, there has been increasing interest recently in measures of physical and mental health.[6] A number of statistical agencies, including in the UK, now gather direct and indirect metrics of people's well-being. Here we map a selection of those alternative metrics, based around *health*, *wealth* and *happiness*.

A different sort of lens comes from viewing these metrics at different spatial resolutions – regional, local authority, postcode even. This allows a "micro-to-macro" jigsaw of the economy to be pieced together, as with other complex systems. Patterns in these systems often self-replicate at different resolutions; they are "fractal".[7] One interesting question is whether economic systems also exhibit self-replicating patterns. If so, this has implications for how we understand and model them.

We consider these questions using a sequence of maps. Many of these maps are not new. For example, Philip McCann from the University's Productivity Insights Network (PIN) has published an excellent book setting out a range of fascinating regional facts and maps. So too have others.[8] These maps provide useful context when testing the Tip O'Neill hypothesis and when modelling and managing the economy.

To provide the clearest visual guide, these maps are scaled by economic rather than geographic size – so-called cartograms.[9] Each region is initially scaled to have the same geographic area and then rescaled in line with economic differences. This means some areas shrink (such as Scotland) while others expand (such as London) even without differences between them. This helps when visualising local differences.

(a)   Differences between regions

To fix ideas, Charts 1a and 1b plot a map and an accompanying cartogram of population by region in the UK and, by way of comparison, Germany. It uses a resolution one-level below the national – administrative "regions" in England and each of Scotland, Wales and Northern Ireland. Comparing the map and cartogram suggests the UK has a significant demographic skew towards London and the South-East. Germany has nothing like the same skew, with the cartogram and map little different.[10]

A key focus of work among economic geographers is the importance of agglomeration effects – that is, increasing returns to economic scale at the spatial level.[11] If those effects are powerful, and if workers are one of their most important sources, we would expect cartograms to have similar properties when looked at by population, income (per head) and wealth (per household). More should not only be merrier but wealthier.

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[6] For example, Case and Deaton (2017).
[7] For example, Viscek, Shlesinger and Matsushita (1994).
[8] McCann (2016), Centre for Cities (2019), What Works Centre for Local Economic Growth (2018).
[9] See Dougenik, Chrisman and Niemeyer (1985).
[10] Put differently, the correlation between geographic area size and population in the UK is in fact slightly negative (-0.05) while it is relatively high and positive (0.7) in Germany.
[11] Viladecans-Marsal (2004) and Rosenthal and Strange (2003), example.

Chart 1a: Map (LHS) and cartogram (RHS) of population in the UK
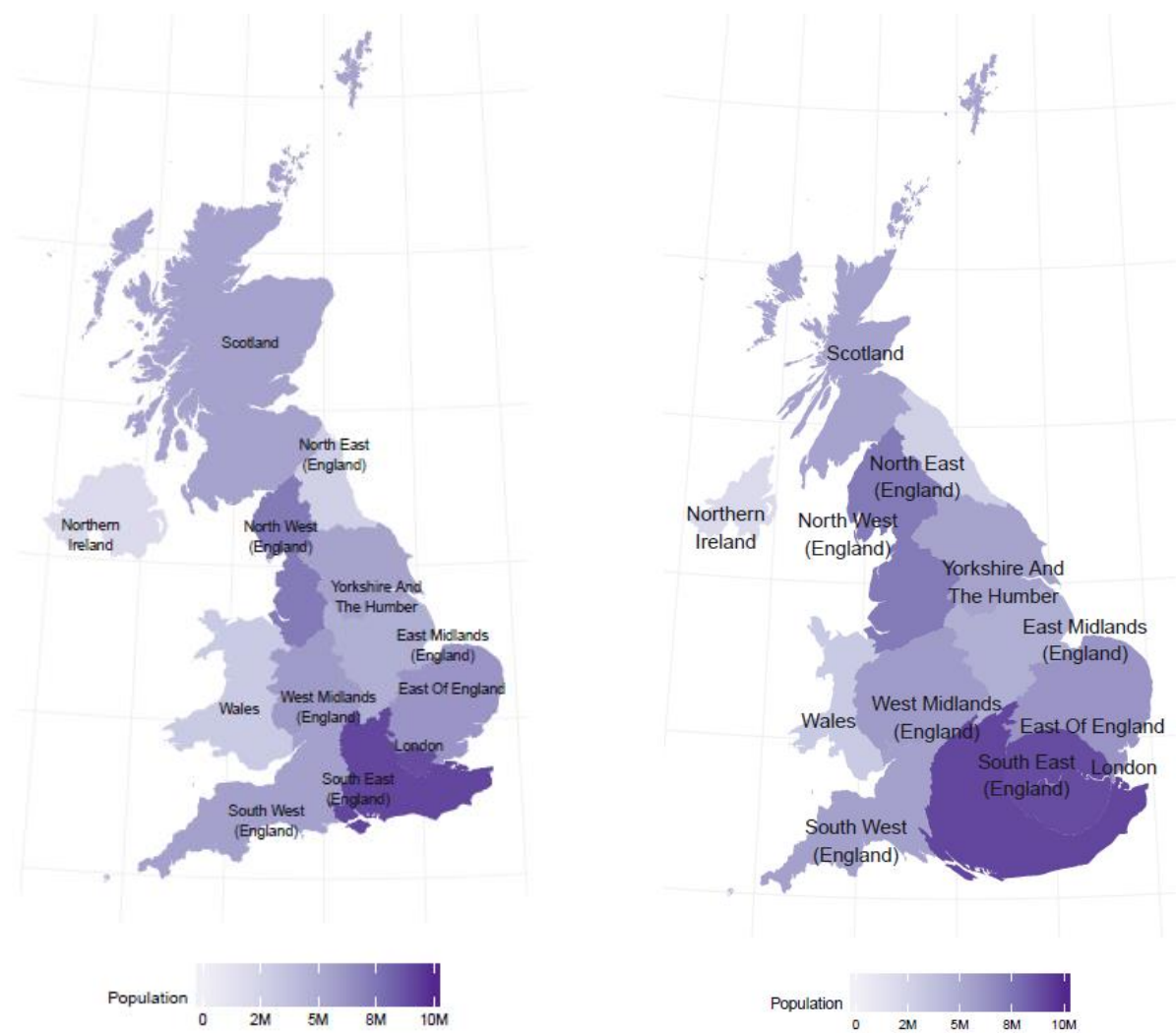
Chart 1b: Map (LHS) and cartogram (RHS) of population in Germany
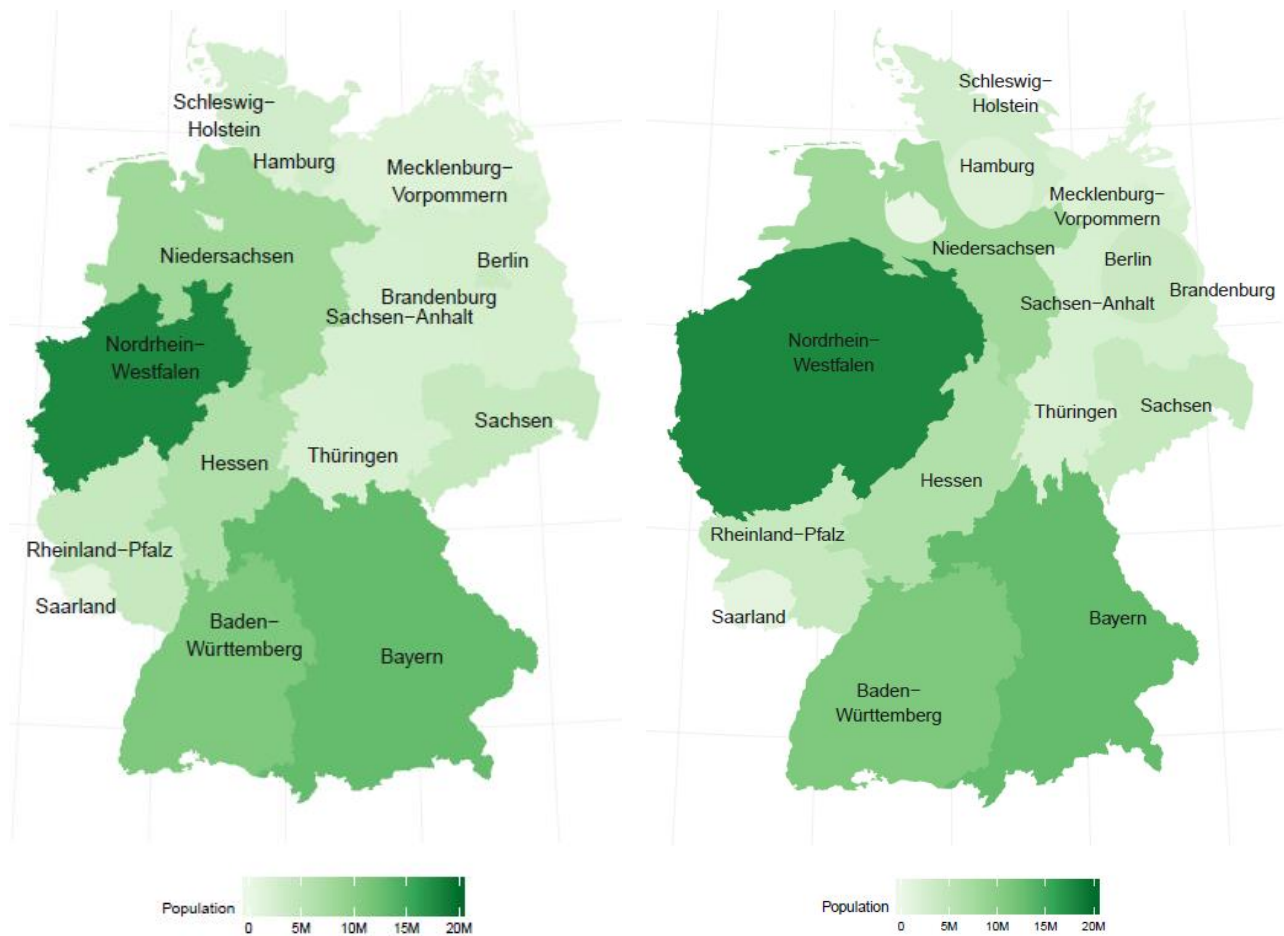
Sources: Eurostat and Bank calculations.
Notes: Charts show population in 2018 for NUTS 1 regions. Cartograms resized by population.

As Charts 2 and 3 show, broadly-speaking that is the case. The income per head cartogram suggests a shrunken North and a swollen South. The gap between richest and poorest region is around 150%. For wealth per household, the North-South divide is also large, with a gap between richest and poorest of 130%. These are striking differences. But are they unusual compared either with the past or other countries?

Chart 2: Cartogram of UK income per head

Sources: Eurostat and Bank calculations.
Notes: Purchasing power standard (PPS) per inhabitant for NUTS 1 regions.

**Chart 3: Cartogram of Great Britain wealth per household**

Sources: ONS Wealth and Assets Survey and Bank calculations.
Notes: Data refer to 2014-16 for NUTS 1 regions, re-sized and coloured by median household wealth. No equivalent data available for Northern Ireland.

On the first of those, Chart 4 plots the distribution of income per head across UK regions on three dates: 1997, 2007 and 2016. All of the distributions are centred on mean levels of income in 2016. This suggests a modest increase in the degree of regional income dispersion over time. The 2016 distribution has somewhat fatter tails, lower and upper, than in earlier periods.[12]

Chart 4: Distribution of UK income per head over time (mean-aligned)
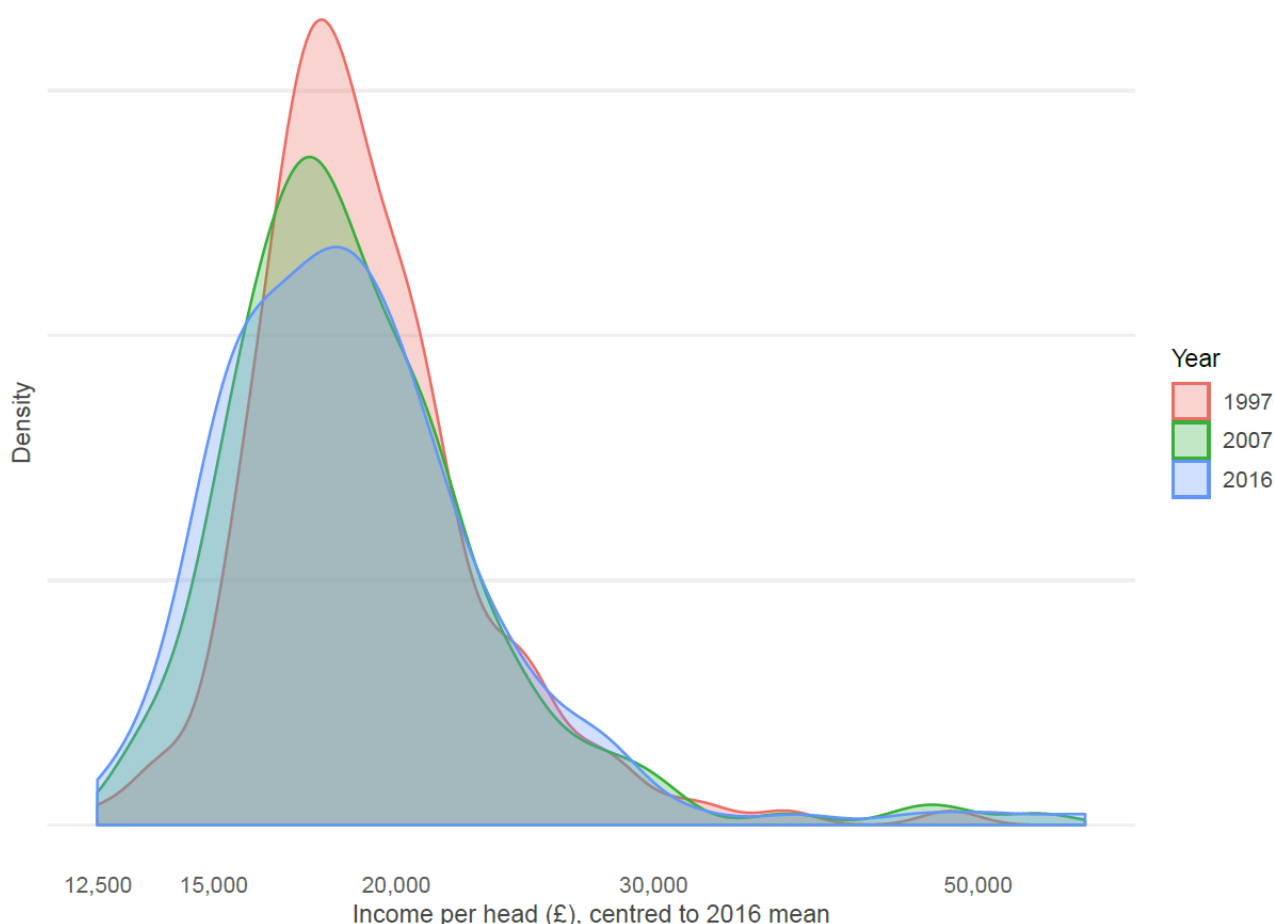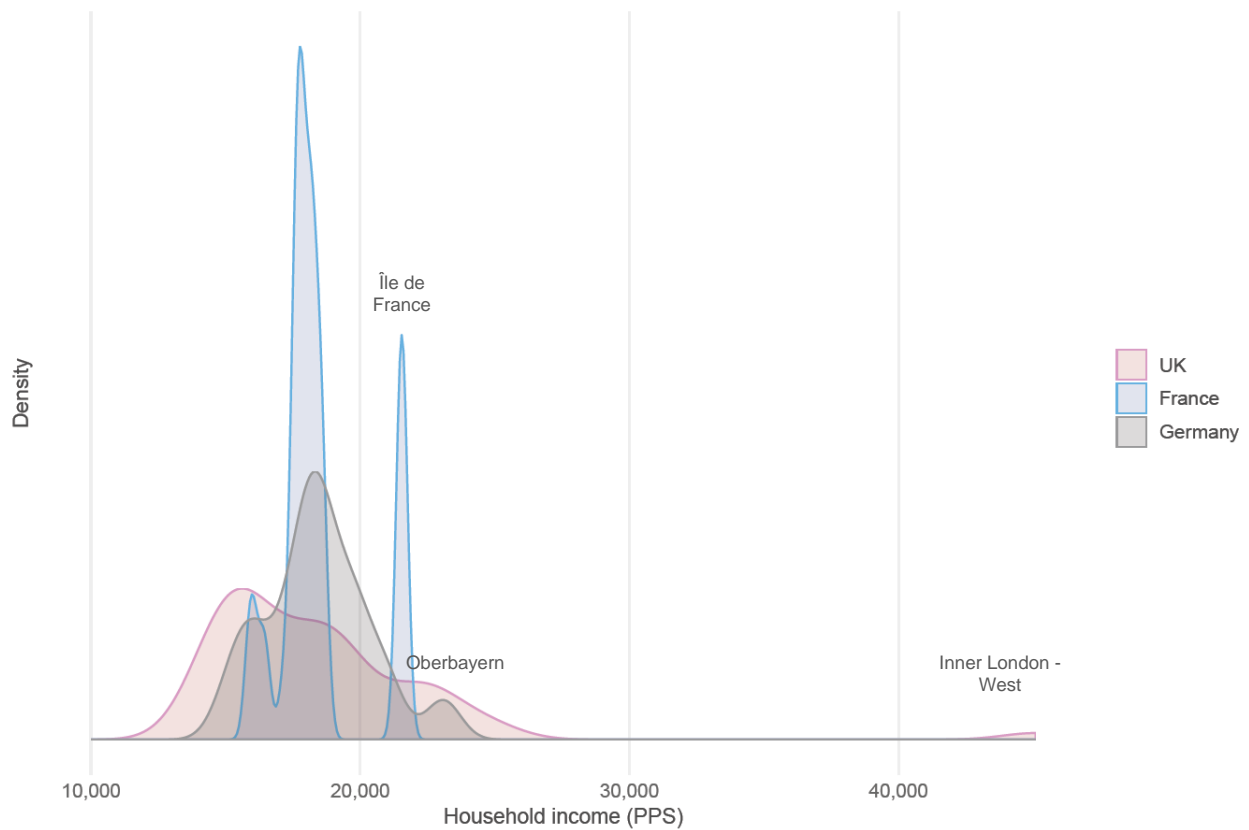

Sources: ONS and Bank calculations.
Notes: Chart shows regional gross disposable income for different time periods at current basic prices, centred around the 2016 mean. Observations for each region are weighted by the population of each region.

Chart 5 compares the regional distribution of income per head in the UK, France and Germany in 2016, again centred on mean income levels in the UK in 2016. It suggests a materially wider regional dispersion in incomes in the UK than in France and Germany. The gap between richest and poorest regions in the UK is almost twice as large as in France and three-quarters larger than in Germany.[13]

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[12] Comparing NUTS 3 regions.
[13] Figures refer to income differences at the NUTS1 regional level, using Purchasing Power Standard (PPS).

Chart 5: Distribution of UK, France and Germany income per head in 2016

Sources: Eurostat and Bank calculations.
Notes: Purchasing power standard (PPS) per household in NUTS2 regions for 2016 centred around the UK mean. Excludes NUTS region 'FRY' ('*Départements d'outre mer*').

These regional differences in GDP are found in alternative metrics of economic health, such as pay (Chart 6).[14] They are also mirrored in *medical* health. Chart 7 plots one measure of medical health by region – average life expectancy. This mirrors regional income differences. Richer people tend to live longer. The gap between highest and lowest life expectancies regionally is around 3.4 years, or 4.2% of the UK average.

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[14] Haldane (2019).

Chart 6: Cartogram of UK pay

Median gross weekly earnings (£)

500   550   600   650   700   750

Sources: ONS Annual Survey of Hours and Earnings (ASHE).
Notes: UK NUTS 1 regions re-sized and coloured by median gross weekly earnings (£) in 2018.

Chart 7: Cartogram of UK life expectancy

Sources: ONS and Bank calculations.
Notes: Life expectancy at birth by local area in the UK (years) for UK NUTS 1 regions, re-sized and coloured by mean life expectancy in 2010-12.

If we turn to an alternative measure of health – psychological health – the picture changes dramatically. Chart 8 plots a subjective measure of well-being on a regional basis.[15] This is the mirror image of the income and wealth maps. Well-being is lowest in the richest region (London) and highest in a region where incomes are low (Northern Ireland). Income may buy you many things, but happiness is not one of them.[16]

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[15] This is based on answers to the question: "Overall, how satisfied are you with your life nowadays?" Other questions regarding well-being yield very similar conclusions.
[16] Easterlin (1974) and Easterlin (2013), for example, point out that while wealthier people tend on average to be happier, happiness does not increase in line with GDP per head. Unemployment and debt arrears also have a large adverse psychological impact on individuals, above-and-beyond their direct impact on income and wealth (Wildman (2003) and Taylor et al (2007)).

While simple, these maps suggest there is important information on economies and societies to be found by peering through different lenses: lenses that operate at different resolutions, as the striking UK regional differences in income, wealth and health demonstrate; and lenses that focus on different economic attributes, as the striking differences between the UK's regional income and well-being maps demonstrate.

Chart 8: Cartogram of UK well-being

Mean wellbeing (life satisfaction score)

7.5   7.6   7.7   7.8   7.9

Sources: ONS Annual Population Survey (APS) and Bank calculations.
Notes: Responses to the question, "overall, how satisfied are you with your life nowadays?" where 0 is 'not at all satisfied' and 10 is 'completely satisfied' for 2016/17. UK NUTS 1 regions re-sized and coloured by mean response.

*(b)*   *Differences within regions*

Given these striking regional differences in health, wealth and happiness across the UK, an interesting supplementary question is how those differences compare *within*-regions. As we alter the resolution at which we view the economy, do these differences narrow? Do economic patterns look different when

comparing them within and between regions? Or are these patterns self-similar at different resolutions, as when we use a microscope to study the shoreline?

Chart 9 provides one visualisation of these patterns at different resolutions. These "violin" plots compare the distribution of income per head at the regional (NUTS 1) level with the distribution at NUTS 2 and NUTS 3 level. If *between*-region income differences were much larger than *within*-region differences, we would expect the violin to be much longer on its left than on its right hand side.

This is clearly not the case. The distributions of income within and between regions are in fact quite similar, at both the NUTS 2 and 3 levels. If anything, the distribution of outcomes *within* each region appears to be a little larger than the distribution between regions. If anything, income inequalities within a region appear to be larger than income inequalities between regions.

**Chart 9: 'Violin' plot of GVA per head**
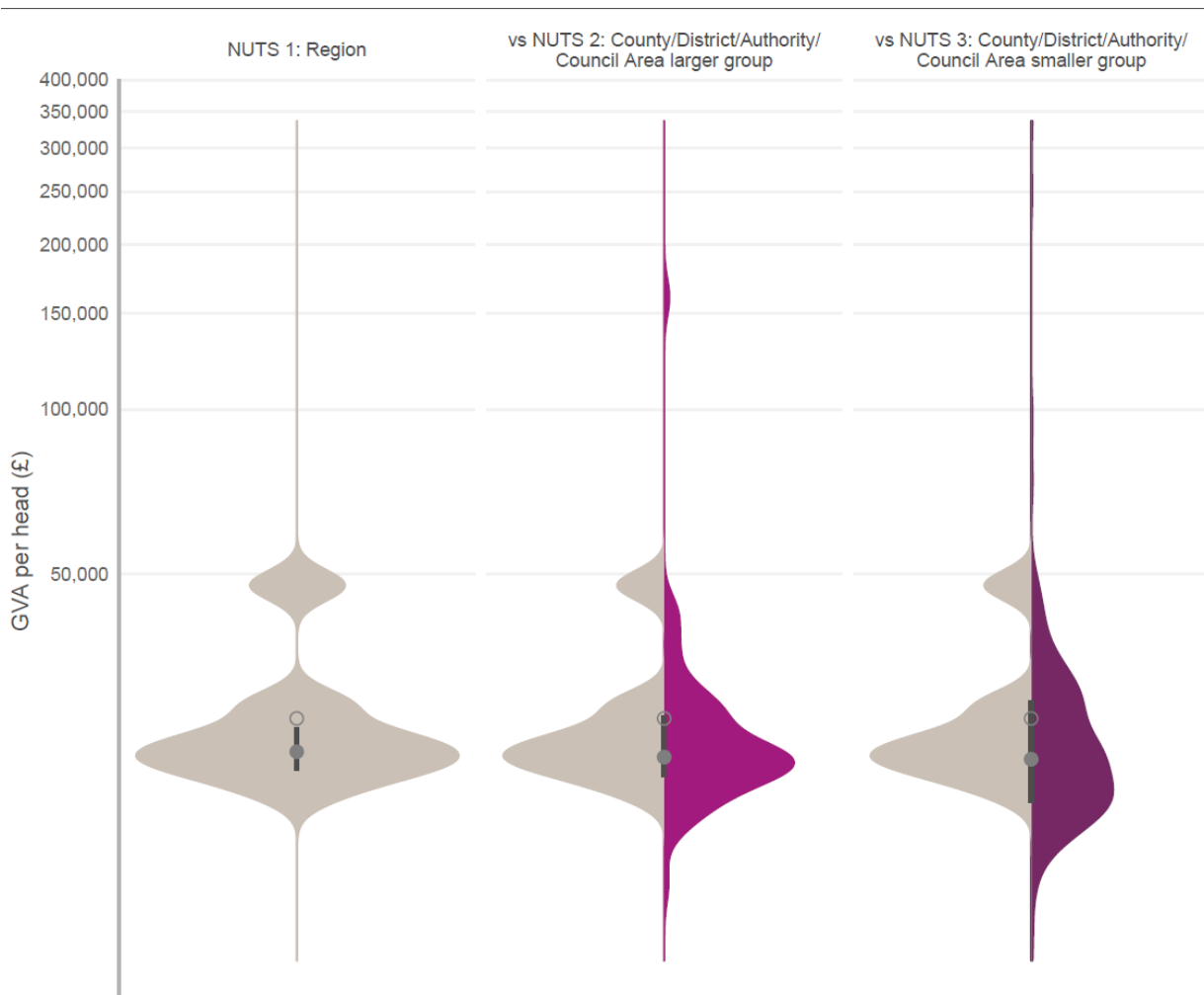
Sources: ONS and Bank calculations.
Notes: Regional gross value-added (GVA, income approach) per head of population at current basic prices for 2017 for NUTS 1, 2 and 3, log-scale. Regional figures weighted by population. Dark bar shows interquartile range, dots show median and circle shows mean.

Charts 10, 11 and 12 are violin plots for wages, health and well-being at higher resolutions. For health and well-being, differences within a region or local authority are materially larger than differences between regions. The standard deviation of health outcomes at the local authority level is almost 3 times larger than at the regional level. The difference between the highest and lowest life expectancy among UK local authorities is 12 years, or 15% of the average expected lifespan.

Chart 10: 'Violin' plot of wages
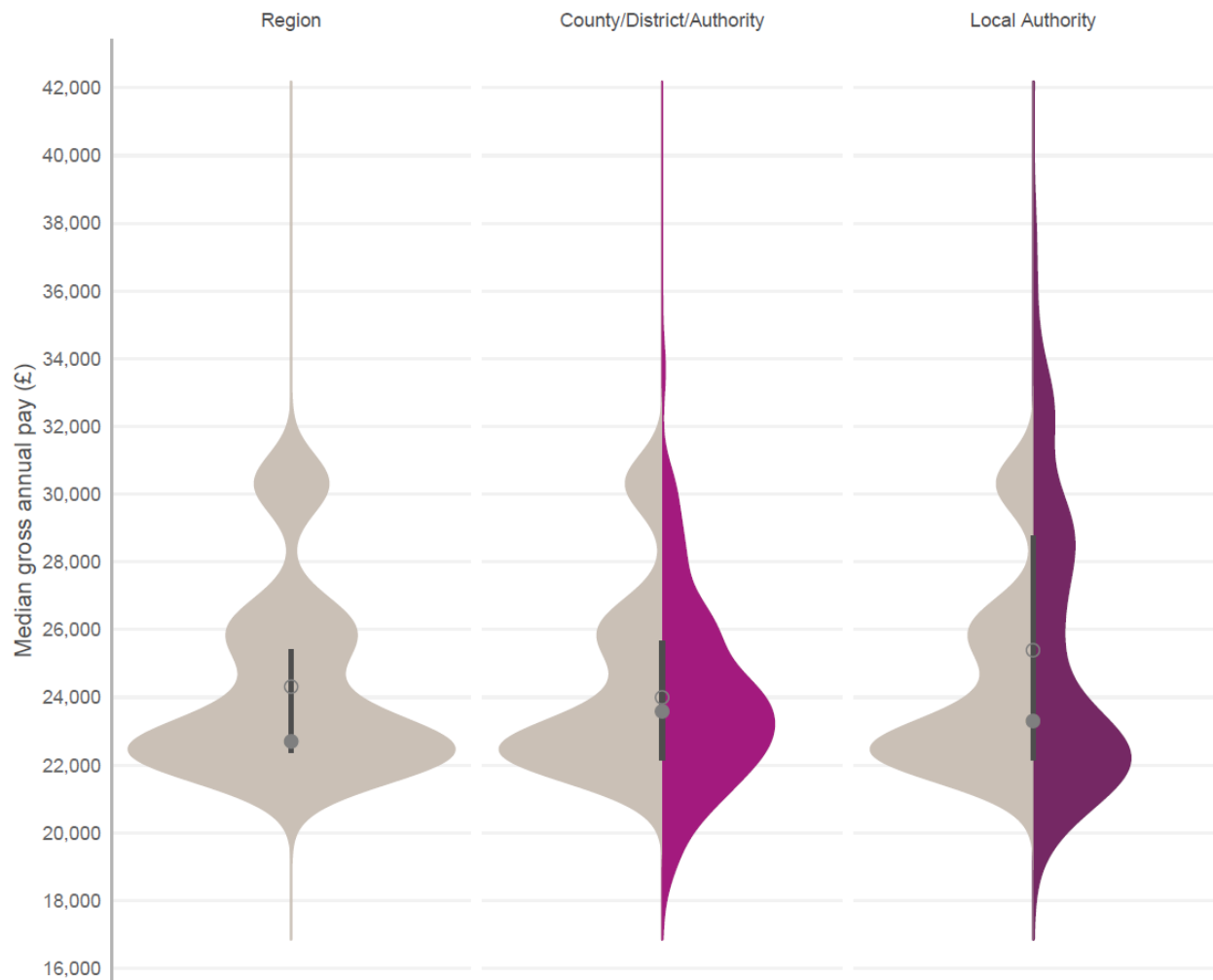
Sources: ONS Annual Survey of Hours and Earnings (ASHE) and Bank calculations.
Notes: Median gross wages in 2018. Regional figures weighted by number of jobs per region. Dark bar shows interquartile range, dots show median and circle shows mean. No Northern Ireland wage data available at NUTS 3 level.

Chart 11: 'Violin' plot of health (life expectancy)
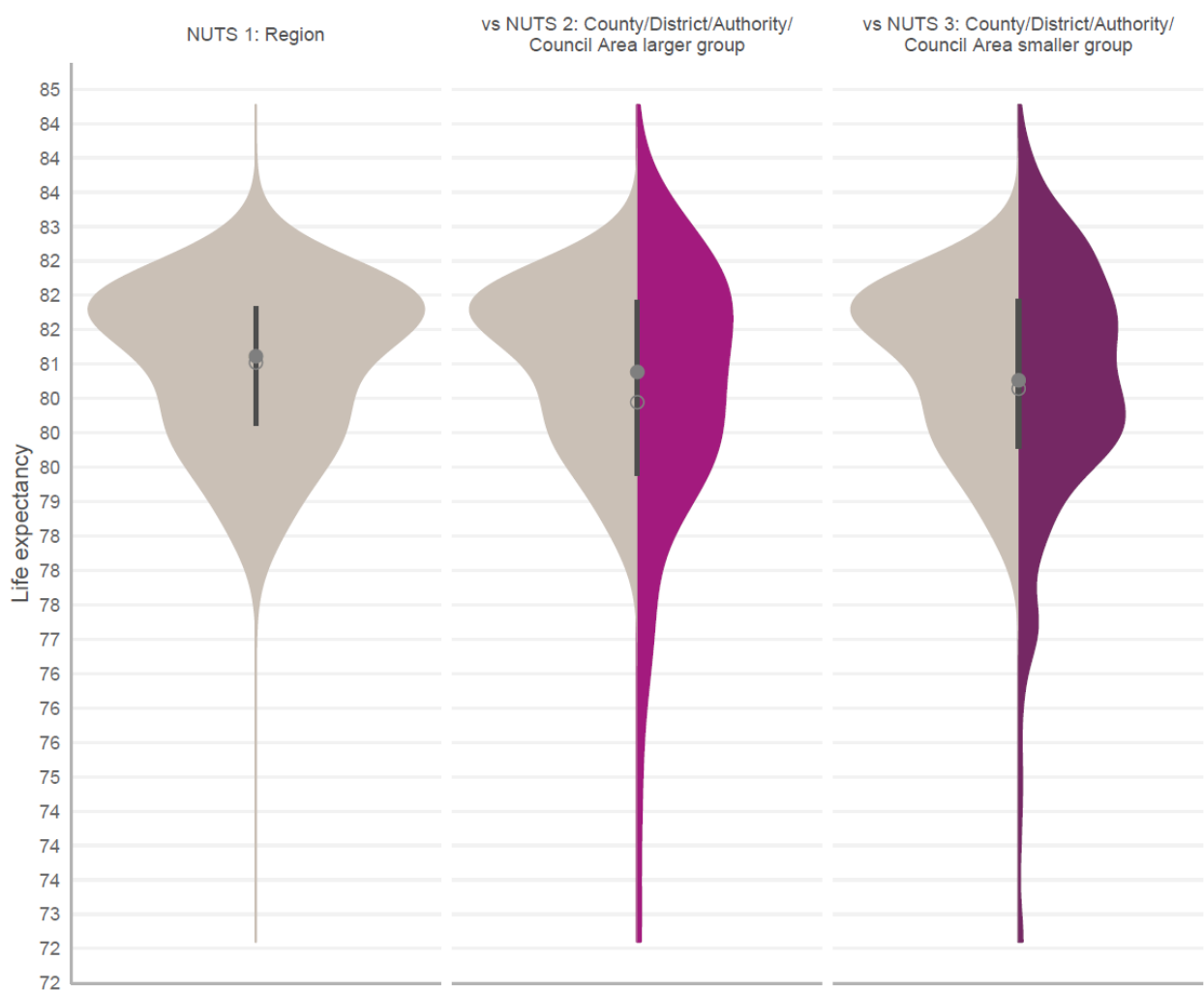
Sources: ONS and Bank calculations.
Notes: Life expectancy at birth for NUTS 1, 2 and 3 regions in 2010-12. Regional figures weighted by population in each region. Dark bar shows interquartile range, dots show median and circle shows mean.

**Chart 12: 'Violin' plot of well-being (life satisfaction)**
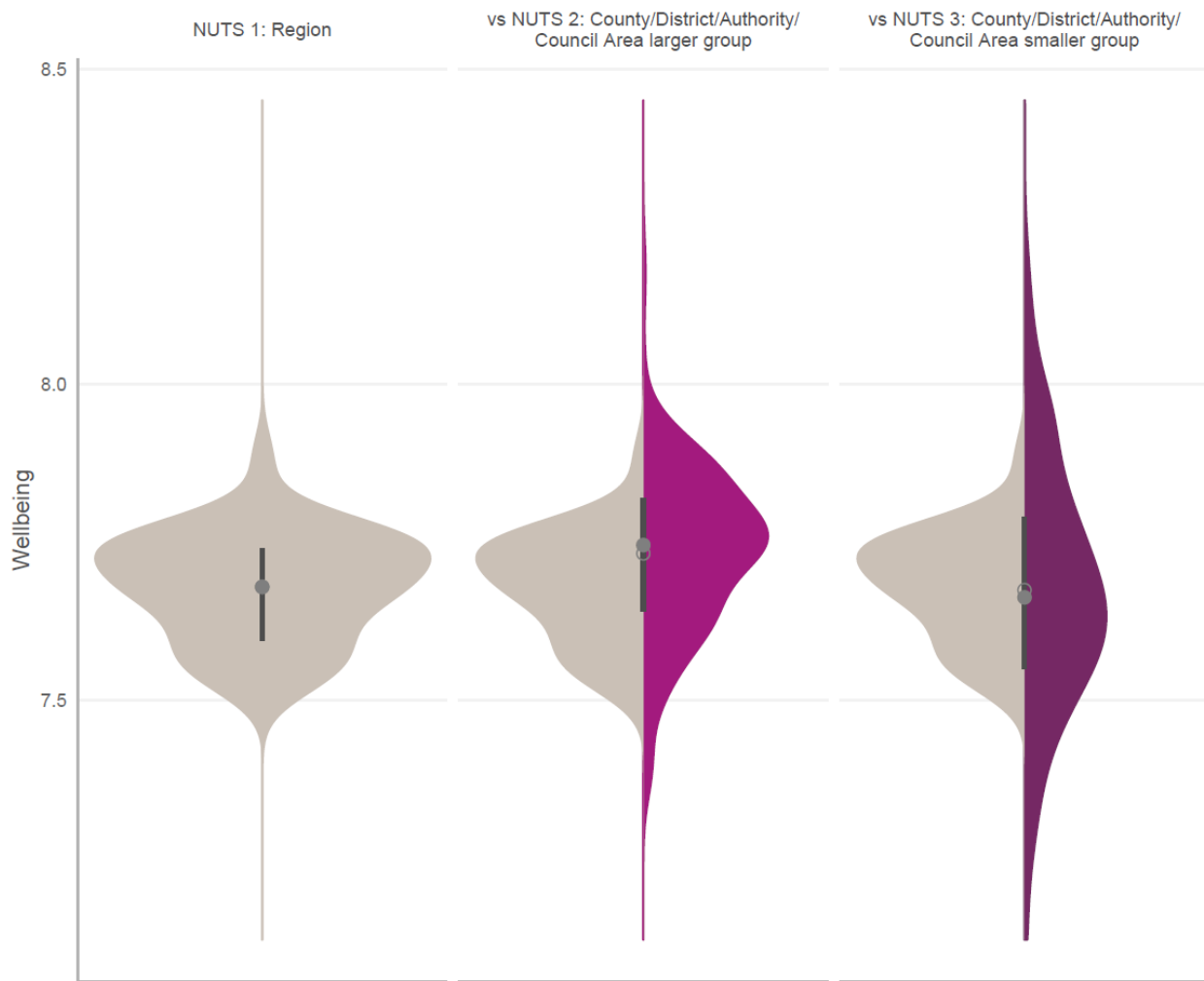
Sources: ONS Annual Population Survey (APS) and Bank calculations.
Notes: Responses to the question, "overall, how satisfied are you with your life nowadays?" for NUTS 1, 2 and 3 where 0 is 'not at all satisfied' and 10 is 'completely satisfied' for 2016/17. Regional figures weighted by population in each region.

Chart 13 plots health perceptions by electoral ward in four big UK cities: Belfast, Cardiff, Edinburgh and (inner) London.[17] The differences are big, with nearly twice as many people perceived to be in bad or very bad health in Belfast than Edinburgh. Even more striking are the differences in the *same* city, however, with adjacent districts reporting bad health differences of between 3% and 25%.

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[17] Data refer to percentage of people in the census rating themselves in "bad" or "very bad" health.

Chart 13: Heat maps of health in Belfast, Cardiff, Edinburgh and Inner London
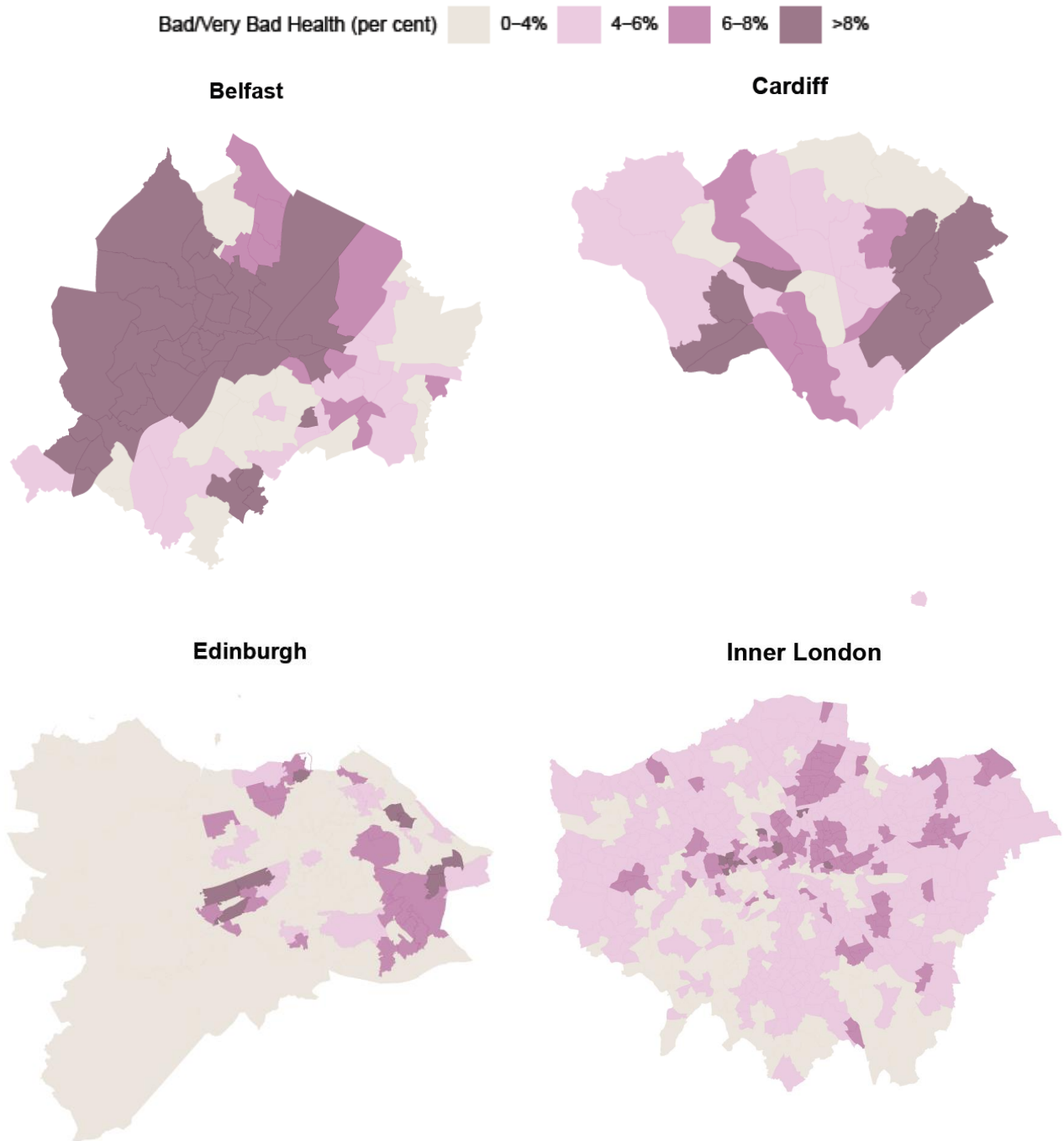
Sources: 2011 Census.
Notes: Data show percentage of respondents declaring themselves to be in bad or very bad health at electoral ward level.

I draw two conclusions from these micro-level visualisations. First, however striking the regional differences in economic and societal health across the UK relative to historical and international standards, these conceal even more striking differences in levels of health, wealth and happiness *within* regions. To the extent there is an inequality issue in the UK, it is as much or more a local rather than regional one.

A second, nerdier, point is what this means for our understanding the economy. Many systems – social, natural and physical – exhibit a pattern in which the distribution of outcomes does not converge at higher resolutions; it remains constant or even expands. These systems have a fractal property with patterns that are self-similar at different levels of resolution. Snowflakes and shorelines are the best-known examples.

The violins charts suggest economic systems may also exhibit some of these properties, with distributions which do not converge at higher resolutions and may even expand. Outcomes in these systems are not distributed like a bell-shaped, Normal distribution. Instead, outcomes are drawn from a Power Law distribution, which has fatter tails and a much greater probability of extreme outcomes.[18]

Chart 14 plots the distribution of health, wealth and happiness across the UK. The straight line shows where outcomes would lie if they were Normally-distributed. Deviations from that line, at its extremities, signify fat-tails. For health and income there is strong evidence of fat tails and Power law distributions.[19]

Chart 14: Power Law tests

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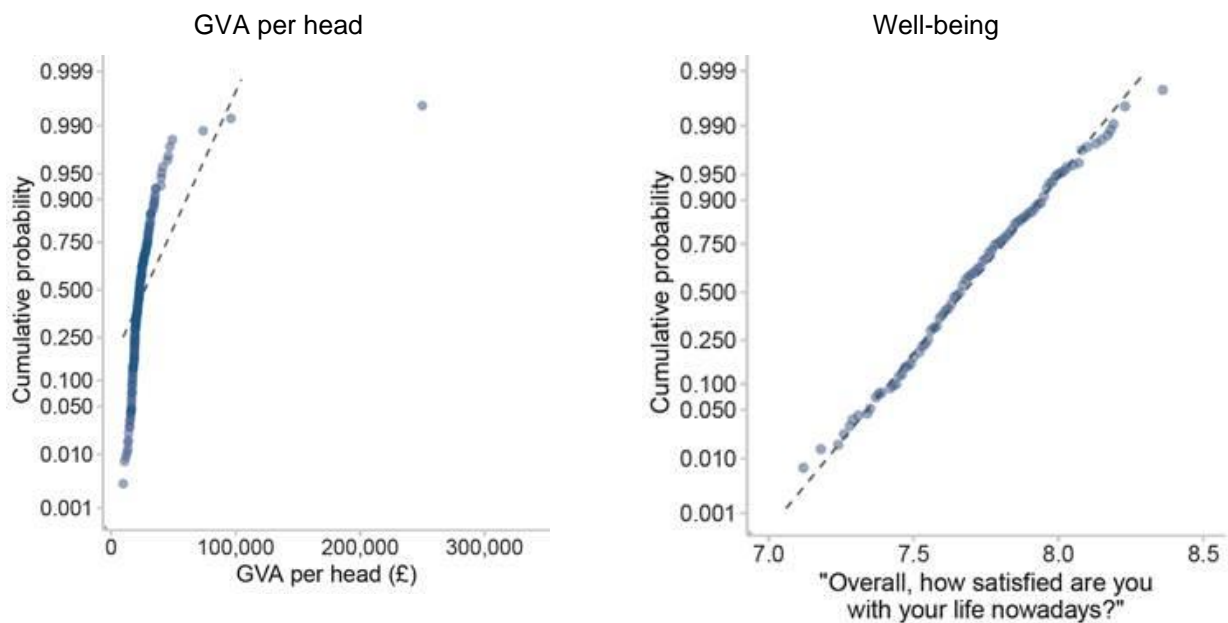
[18] Haldane (2012) discusses Power Law distributions as they apply to economic and financial variables.
[19] Haldane (2012).

Wages	Health (life expectancy)
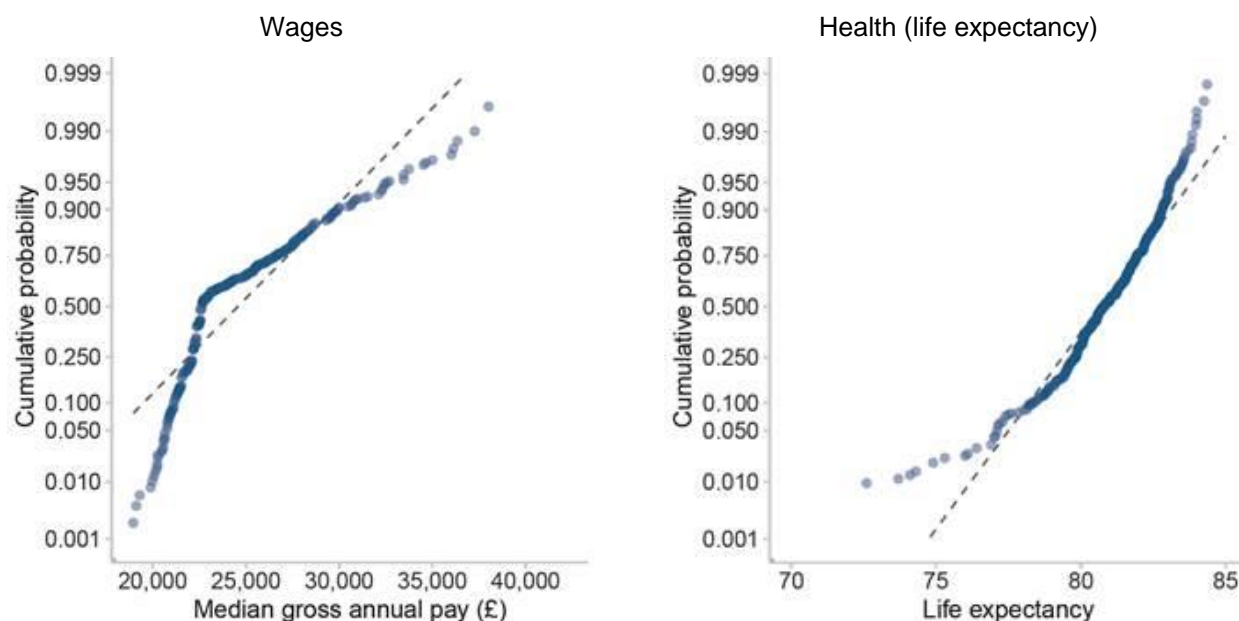
Sources and notes: as per violin plots in Charts 9-12.

Fat-tails and Power Law distributions are associated with systems that are complex and adaptive. The best definition of complexity is, for me, the one provided by Herbert Simon back in 1962: "one made up of a large number of parts that interact in a non-simple way".[20] That description fits our maps rather well. They are certainly made up of a large number of distinct parts, even within geographically-concentrated areas.

If the economic system is complex, in the sense of Simon, this carries important implications for understanding and modelling these systems. As with the body, to understand the dynamics of a complex system it is crucial you study the micro-level moving parts. It is equally important to understand interactions among these parts. What do we know about interactions among the economy's moving parts?

(c)   Movements between regions

In economic systems, interactions occur among all of the factors involved in production and consumption decisions – people, money, goods and services. Capturing flows of these factors, and their interactions, is crucial for understanding how a complex economic system will function. Below I consider flows of money, goods and services. Let me start by considering flows of people.

Chart 15 plots migration in and out of various regions in 2016-17, expressed as a proportion of the regional population. Even *gross* inflows and outflows are relatively modest, varying between 4% (London) and ½% (Northern Ireland). Net *flows* of people are even more modest, in all cases bar London averaging less than 0.6%. One of the reasons regions are distinct may be because of their ring-fenced populations.

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[20] Simon (1962).

Chart 15: Migration inflows and outflows between different UK regions
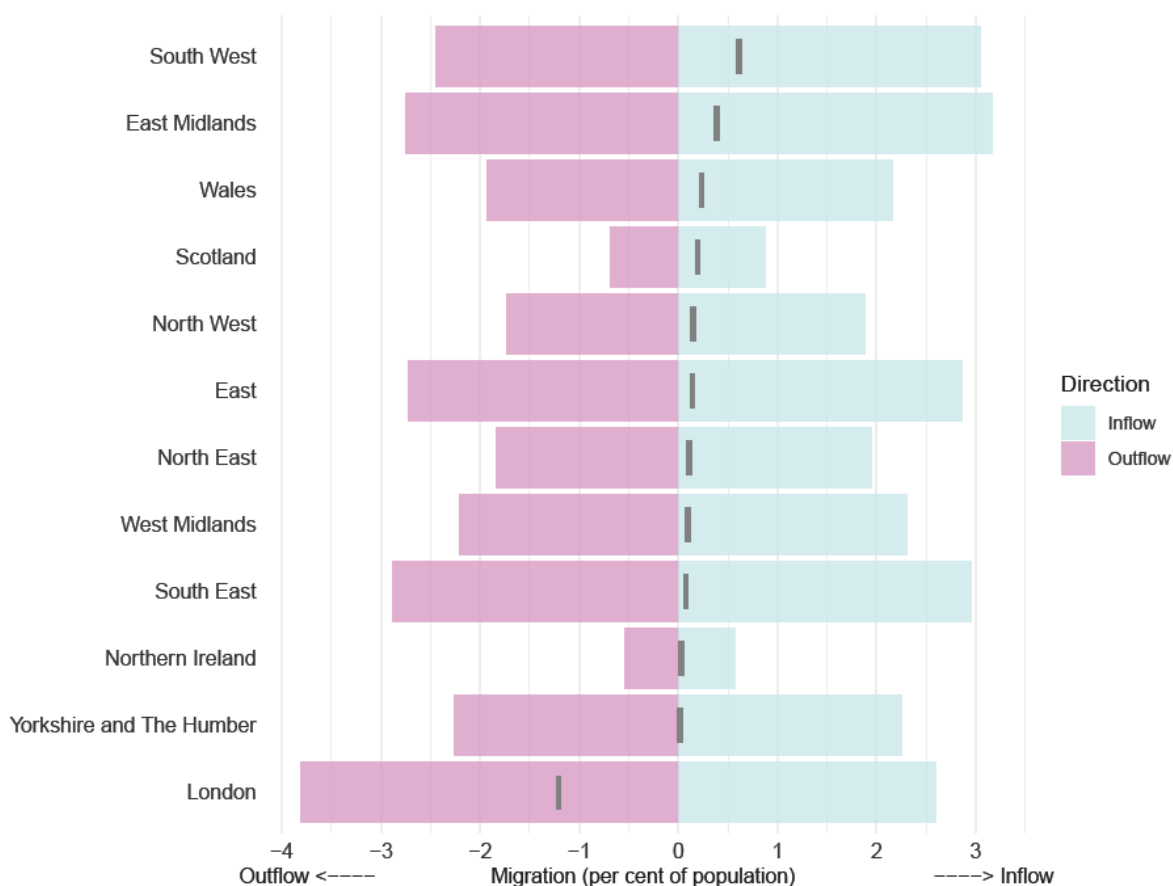
Sources: ONS Local Area Migration Indicators and Bank calculations.
Notes: Data refer to mid-2016 to mid-2017, as a percentage of 2017 population.

Of course, people living in one region can still commute into another for work purposes. Table 1 looks at commuting destinations across UK regions, as a percentage of each region's population. With the exception of London and the South-East, worker flows from outside of the home region are modest, averaging only 5% of the working population. Even when looking at flows of workers, most regions are self-contained and local.

Table 1: Commuting flows between UK regions (percentage of workers resident in each region)

						Place of work						
Place of residence	NI	Sco	NE	Wal	NW	SW	Y&H	WM	EM	Eas	SE	Lon
Northern Ireland	99.4	0.1	0	0	0	0	0	0	0	0	0	0
Scotland	0	98.5	0.2	0	0.1	0	0.1	0	0	0.1	0.1	0.1
North East	0.1	0.2	97.3	0	0.2	0.1	0.9	0.1	0.1	0.1	0.1	0.1
Wales	0	0.1	0	95.9	1	0.9	0.1	0.7	0.1	0.1	0.2	0.1
North West	0.1	0.3	0.3	1.9	95.3	0.3	1.3	1	0.6	0.3	0.3	0.3
South West	0	0.1	0.1	0.7	0.1	94.9	0.1	0.7	0.2	0.2	1.9	0.5
Yorkshire & Humber	0.1	0.2	1.5	0.1	1.1	0.2	94.4	0.3	2.1	0.3	0.2	0.2
West Midlands	0.1	0.1	0.1	0.8	1	1	0.2	93.4	2.9	0.3	0.5	0.4
East Midlands	0.1	0.1	0.1	0.1	0.7	0.2	2.4	2.7	91.7	1.9	1	0.5
East	0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	1.2	90.2	1.5	8.3
South East	0	0.1	0.1	0.2	0.2	1.8	0.2	0.5	0.8	2.1	89.4	10.9
London	0	0.1	0.1	0.1	0.2	0.4	0.1	0.3	0.3	4.4	4.7	78.6

Sources: Nomis and Bank calculations.
Notes: Percentage of each region's workers commuting from each residential region.

These flow data provide a useful lens on local economic eco-systems. As an example, Chart 16 plots the time to get to work (in minutes) against the distance to work (in km) across the UK's regions. Most regions outside London and the South-East are tightly clustered, with an average commute time of 27 minutes and distance of 16 km. Consistent with other evidence, this suggests most regions are local economically.

Chart 16: Distance vs. time to work
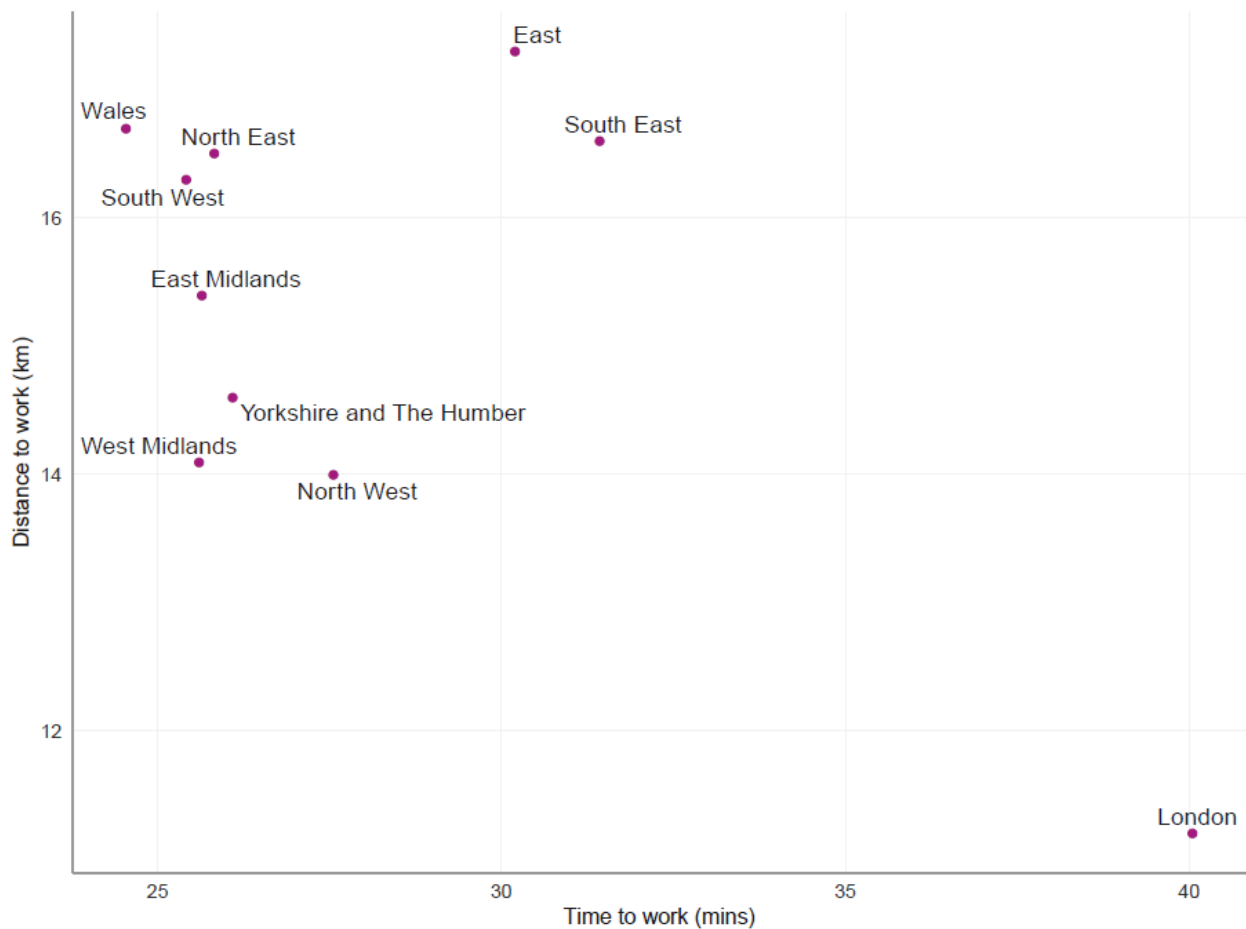
Sources: ONS Labour Force Survey, 2011 Census and Bank calculations.
Notes: Average distance travelled (km) and usual time (minutes) from home to work by NUTS 1 region in England and Wales.

The situation is somewhat different in London. The average commute distance is materially shorter (11km) but the average travel time almost doubles at (40 minutes). A cartogram of commute times makes this point strikingly (Chart 17). Contrary to popular belief, London is life in the slow lane. As we know commuting often detracts from people's well-being, this cartogram perhaps explains why Londoners are richer but more miserable.[21]

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[21] For example, Office for National Statistics (2014) and Novaco and Gonzalez (2009).

Chart 17: Cartogram of UK travel time to work

Mean travel time to work (mins)
0   10   20   30   40   50

Sources: ONS Labour Force Survey, 2011 Census and Bank calculations.
Notes: UK local authorities re-sized and coloured by mean travel to work time (minutes).

Modelling the Economy

How can these micro-level data help when modelling the economy? Economists and policymakers typically use highly-aggregated models which operate at an economy-wide level, often comprising a small number of "representative" agents. In their most aggregated versions, there is a single representative household and company. The most widely-used is the Representative Agent New Keynesian (RANK) model.[22]

RANK-type models have real virtues. They are underpinned by an optimising view of individual human behaviour and, in this sense, can be said to be "micro-founded". They are explicitly identified, in the statistical sense, and parsimonious. These characteristics mean these models can often offer deep insight into comparative static questions about the impact of changes in the deep parameters of an economy, such as shifts in risk-aversion among households or in levels of technology among firms.[23]

There are also, of course, costs of simplicity. The most serious is the inability of these models often to fit the macro-economic facts at business cycle frequencies, particularly at times of economic stress.[24] RANK models fared poorly in capturing the dynamics of the economy either side of the global financial crisis. At the very time it was most interesting and important, these models were found wanting as a guide to the fortunes of the economy and economic policy.

One response has been to develop models that relax the representative agent assumption. So-called Heterogeneous Agent New Keynesian (HANK) models comprise distinct agents with distinct behaviours. As importantly, these models capture interactions among agents.[25] While it is heterogeneity that is often emphasized, it is *interactions* between agents that is most important for replicating real-world dynamics.

Consider the dynamics of two very simple systems: a single and double pendulum. The single pendulum is a representative agent model. Once disturbed, its motion is regular and its distribution normal (Figure 1, LHS). The double pendulum involves two identical representative agents which interact. Its dynamics are complex and highly non-linear and it is Power Law distributed (Figure 1, RHS). Even simple interactions among representative agents generate complex system dynamics.
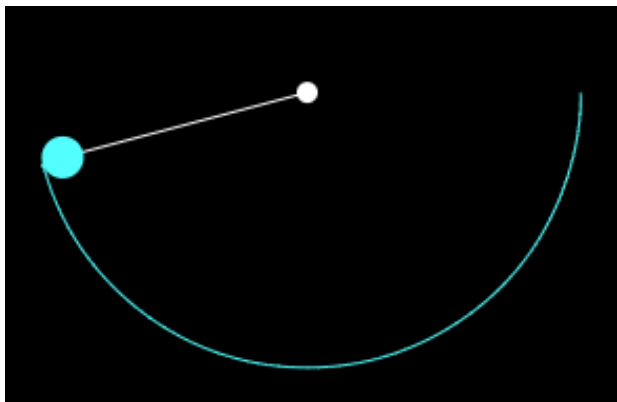
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[22] For example, Galí (2015).
[23] For example, Kydland and Prescott (1982).
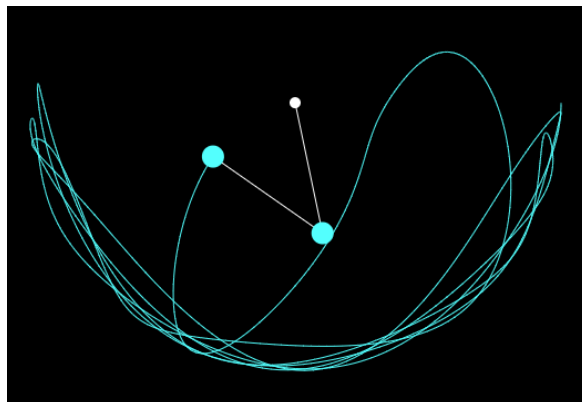[24] Haldane (2016), Haldane and Turrell (2018).
[25] For example, Kaplan, Moll and Violante (2018).

Figure 1 : Single and double pendulum

Single pendulum	Double pendulum

Sources: https://codepen.io/anon/pen/XQLNaZ

HANK-type models do a better job of capturing heterogeneity across agents than their RANK cousins. The number of interactions among their internal moving parts is nonetheless heavily constrained. Certainly, they do not come close to capturing the granularity, spatially or sectorally, that exists in real-world economic systems. Are there alternative modelling approaches that capture more of these moving, interacting parts?

Agent-Based Models (ABMs) use a larger array of distinct agents and permit a far-larger scale of interaction among them.[26] They have been used extensively to model complex systems – natural systems (rainforests and oceans), physical systems (electricity grids and war zones) and social systems (swarms of birds and bees).[27] These are systems where it is recognised that an understanding of interactions among the internal moving parts is crucial for capturing behaviour of the system as a whole, in line with Simon's dictum.

For economists used to dealing with highly-aggregated models, the very dimensionality of ABMs is striking. The largest in physics can now simulate interactions of up to 400 billion distinct particles at any one time.[28] That is around 50 times as many agents as there are humans on the planet. By way of comparison, the largest-scale macro-models would typically have fewer than 10 distinct agent types.

ABMs have been used to study the economy, albeit not very extensively.[29] The Bank has recently used them to model the housing and corporate bond markets, both of which exhibit non-linear dynamics due to complex interactions among agents.[30] These models have also been used to run hypothetical policy simulations, in particular for macro-prudential policies.[31] These models are no free lunch. They pose difficult choices, such as where to strike the balance between realism (complexity) and parsimony (simplicity).

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[26] Farmer (2019) discusses agent-based models in the context of complexity economics.
[27] For example, Ge et al (2018), Ge and Polhill (2016) and Heppenstall et al (eds.) (2012).
[28] https://arxiv.org/abs/1112.1754
[29] For example, Cristelli, Pietronero and Zaccaria (2011) and Napoletano, Gaffard and Babutsidze (2012).
[30] Baptista et al (2016) and Braun-Munzinger, Liu and Turrell (2016).
[31] Baptista et al (2016).

We typically define models as simplified abstractions of reality, partly for reasons of practicality given humans' limited capacity to track too many moving parts. But computers these days can keep track far better than any human. If the largest ABMs have a dimensionality greater than our population, why not model the economy at its highest possible resolution? Why be abstract if you can be exact? That would be a very different conception of the term "micro-founded".

This may sound like science fiction. Yet we already have practical examples of just that, starting at the highest level of resolution – the firm. In 1956, Jay Wright Forrester, an electrical engineer, switched from devising systems for detecting incoming Soviet nuclear bombs to designing systems for understanding production problems in companies. He developed the first computer models of how companies operated. In so doing, he founded the discipline that would become "system dynamics".[32]

In line with Forrester's initial insight, one of the most interesting developments recently when understanding the dynamics of companies is the creation of so-called "digital twins".[33] These are a DNA-level digital clone of a company, tracing the interactions among its moving parts. A digital twin is a high-resolution, dynamic model of a firm-level micro-economy that can be used both to understand and to simulate a company's operations, however complex. Their use among frontier companies is increasingly commonplace.

The data necessary to calibrate these digital twins is considerable, but also increasingly commonplace.[34] Twenty years ago, the large American retailer Walmart created a system allowing them, and their suppliers, to monitor their complex supply-chain in close to real time.[35] This transformed inventory management at Walmart and its suppliers. Twenty years on, these real-time data systems are rapidly becoming the norm.

At the next level of resolution, could a digital twin be created at a town or city level? Having started with the firm, Jay Wright Forrester's next project was to simulate a city, in an attempt to understand and help solve the US's "urban crisis" of the 1960s. Forrester developed DYNAMO, a computer-simulated model of a city comprising 150 equations and 200 parameters. His book *Urban Dynamics*, published in 1969, set out how these computer models could be used to understand the evolution of cities.[36]

Reading Forrester's book in the 1980s, video-game developer Will Wright had an idea for creating a game involving building a dynamic model of a city. The result was *SimCity* (Figure 2). This quickly became one of the most popular video games of its era. Computer-simulated video games quickly came to be used to solve real-world city planning problems. Subsequently, ABM-like models of simulated cities have found widespread use for urban planning and development.[37]

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[32] For example, Karnopp, Margolis and Rosenberg (1990).
[33] Shaw and Fruhlinger (2019).
[34] Bolton et al (2018) have discussed the possible guiding values for a national digital twin framework as part of work on behalf of the Centre for Digital Built Britain.
[35] Hardgrave et al (2006).
[36] Forrester (1969).
[37] For example, Motieyan and Mesgari (2018).

Figure 2: *SimCity*

Sources: Electronic Arts, available at: https://help.ea.com/en-us/help/simcity/simcity-buildit/all-about-regions-in-simcity-buidlit/

If creating a digital twin is possible at the firm and city-region level, might it be feasible *economy-wide*? An economy-wide map constructed at the microscopic level, and an accompanying digital twin tracking flows among the moving parts, is an intriguing vision of how a future economic model might be constructed. Paul Clarke, Chief Technical Officer at Ocado, has recently set out a vision of smart cities and communities, with tracking and modelling of flows through drones, robots and smart infrastructure, which is in this same spirit.[38]

Such a model is not without precedent. In 1949, the New Zealand economist A W Phillips built a machine in his landlady's garage in Croydon using liquid and tanks to illustrate the circular flows of income and interactions in an economy (Figure 3). This early analogue computer was not for show; it was used to understand the economy and simulate policy before digital computers existed. Working versions still exist. The model I have sketched is a high resolution, digital version of the Phillips machine.

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[38] Clarke (2018).

Figure 3: Phillips machine
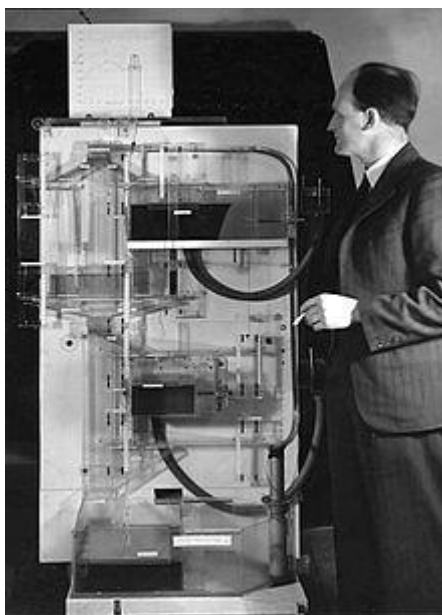
Sources: Image available at https://en.wikipedia.org/wiki/William_Phillips_(economist)

Building a microscopic-level model of the economy is an enormous undertaking if it were to be attempted top-down. But that traditional top-down approach to model-building may itself need to be inverted. Clarke's suggested approach is to build this model bottom-up. The map would be crowd-sourced and then stitched together, a Wikipedia-style or micro-to-macro approach to model-building.

An economy-wide digital twin would, in a very literal sense, be micro-founded, but in a diametrically-opposing way to existing models. The foundations of this digital twin are constructed not on micro theory, but micro fact. If you were looking for clues on the feasibility and desirability of such an endeavour, consider the way in which scientists have gone about understanding and simulating another complex, adaptive system which affects everyone's everyday lives – the weather.

Weather systems are the archetypical complex, adaptive system, the very origin of the concept of chaos.[39] Yet despite their chaotic properties, our understanding of weather systems, globally and locally, has improved dramatically over recent decades. Errors in forecasting the weather have halved in a generation, a remarkable improvement. The reason for that improvement is not because of a great leap forward in weather theory; it is because of improvements in micro-level weather facts.

Meteorologists piece together their models of weather systems from very high resolution readings. It is this improvement in data resolution that has held the key to improvements in weather forecasting. These readings come from a range of meteorological agencies, as well as from private companies and citizens. These data can be pooled and stitched to give a global map. Weather data is crowd-sourced, Wikipedia-style, and then centrally stitched, a micro-to-macro approach.

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[39] Lorenz (1963).

As these data are collected in close to real-time, weather simulations are available in close to real-time. This also allows us to study weather systems at a wide variety of resolutions – globally, nationally, regionally, down to the local village. This not only helps people better understand the environment facing them. Importantly, it improves the decisions they make, nationally and locally, governments and citizens.

Weather is by no means a unique example. Micro-level data, digital twins and massive-scale simulations are being used to better understand all manner of other systems at all manner of resolutions – from the sub-atomic scale when seeking the Higgs-Boson, to the global scale when modelling flows across oceans, the world wide web and galaxies. All have benefitted from drawing on mass micro-level data, crowd-sourced, centrally-stitched, micro-to-macro.

Until recently, fewer such high-resolution data existed when it came to tracking flows of goods and services, people and money through our economy. That is changing. These data increasingly exist in companies, whose management systems capture activity in close to real time. They exist through now-ubiquitous sensor, camera and satellite technology. And they exist in governments, local and central, in the form of administrative data on people, goods and money flows.

Increasingly, these data are being put to use to understand the economy.[40] In the UK, the Office for National Statistics recently started publishing a range of high frequency economic indicators, based on such sources as administrative data on VAT returns and geospatial data on traffic flows. The Bank has made increasing use of these sorts of data in its own real-time assessment of the economy. Let me give a couple of examples.

One topic attracting attention recently has been the economic consequences of a disruptive Brexit. One of the key channels through which this economic disruption might take place is the inability of lorries to move seamlessly through UK ports. To track this disruption in the event of a disorderly Brexit, the Bank put in place a system for monitoring traffic flow around the UK's main ports using geospatial data from Google Maps. This allowed close to real-time monitoring of potential port bottlenecks.

As an illustration, Chart 18 plots traffic times into and out of Dover during February, March and April this year. The first highlighted mini-spike in traffic times is the Friday evening and Saturday morning before the school holidays. The second is Easter weekend. A disruptive Brexit would potentially have pushed these needles off the Richter scale. There is huge potential for more extensive use of geospatial data such as these to track goods and service flows across the economy, in normal as well as abnormal times.[41]

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[40] Haldane (2018a).
[41] A geospatial commission has recently been set up, under Sir Andrew Dilnot, to look at precisely these questions. See Geospatial Commission (2019) for a discussion of its work to date and longer-term priorities.

**Chart 18: Traffic times into and out of Dover**
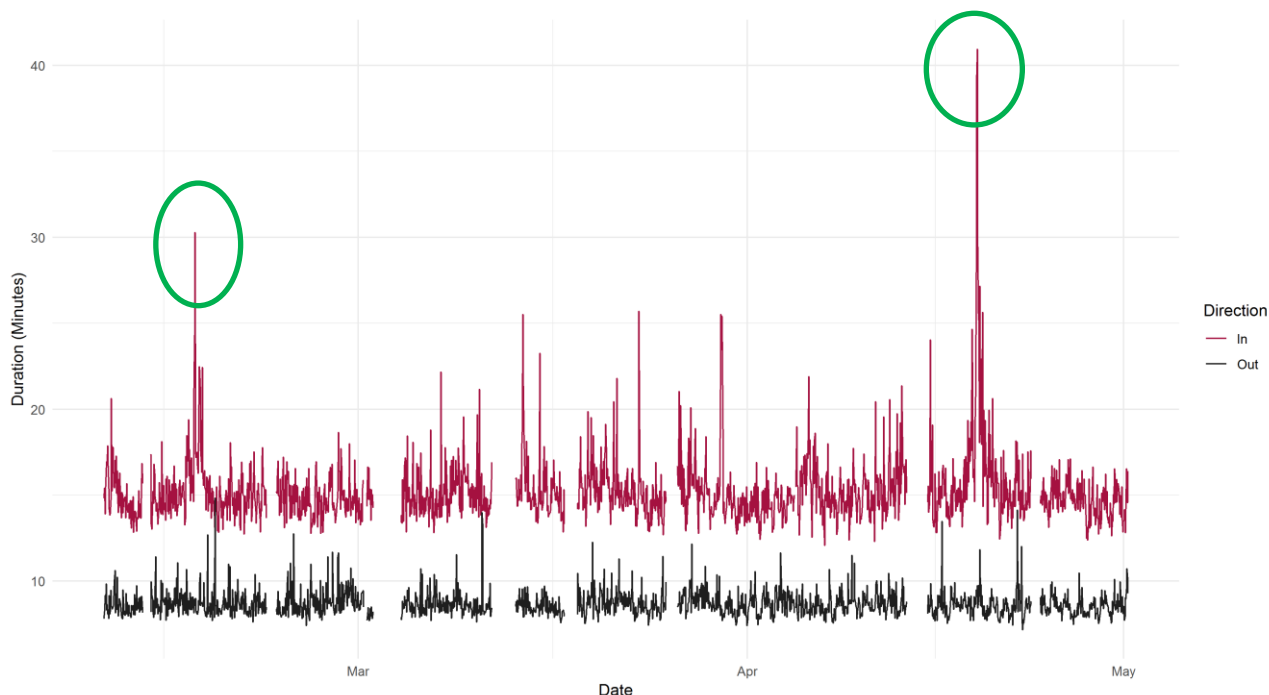
Sources: Google Maps API and Bank calculations.

A second example concerns the housing market. This, too, is a local market. That is why the most popular house-buying show on TV is called "Location, Location, Location". Two colleagues at the Bank, Fergus Cumming and Al Firrell, have recently used a database on all mortgages granted in the UK since 2005 to explore house-moving patterns.[42] The results are preliminary, but let me share some of the early findings to demonstrate what might be feasible.

Chart 19 plots the frequency of house moves at different distances in 2018. The modal distance of a house move is less than 10km. This is twice as likely as the second most popular distance – 10-20km. In other words, a gravity (distance) model of house moves fits the data, with around one-third of all house moves within 50km. Most house moves are local. Most, but by no means all. The median move is a little below 100km, the mean 130km. There is a longer tail of long-distance house moves than I would have predicted.

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[42] Although this may sound simple, it involves a complex matching algorithm to identify housing chains, similar to Chakraborty, Gimpelewicz and Uluc (2017).

Chart 19: Distribution of house moves by distance (mortgage-to-mortgage movers in 2018)
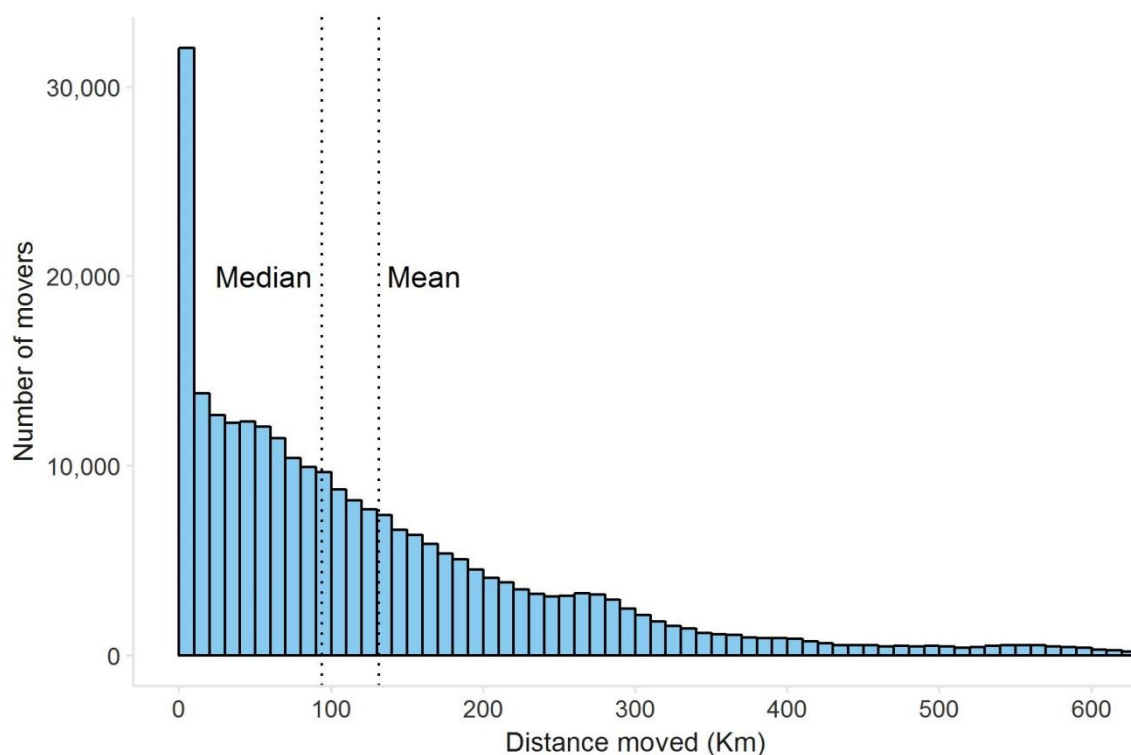
Sources: Product Sales Database and Bank calculations.

Part of the explanation lies in regional and demographic differences. People outside London and the South-East – for example, in Scotland – are much more likely to move greater distances (Chart 20). Older people (over 46) are more likely to move larger distances than younger people (under 33) (Chart 21). And richer people are less likely to move larger distances than poorer ones (Chart 22).

Chart 20: Distribution of house moves by distance in different regions (mortgage-to-mortgage movers in 2018, moving to South-East England and Scotland)
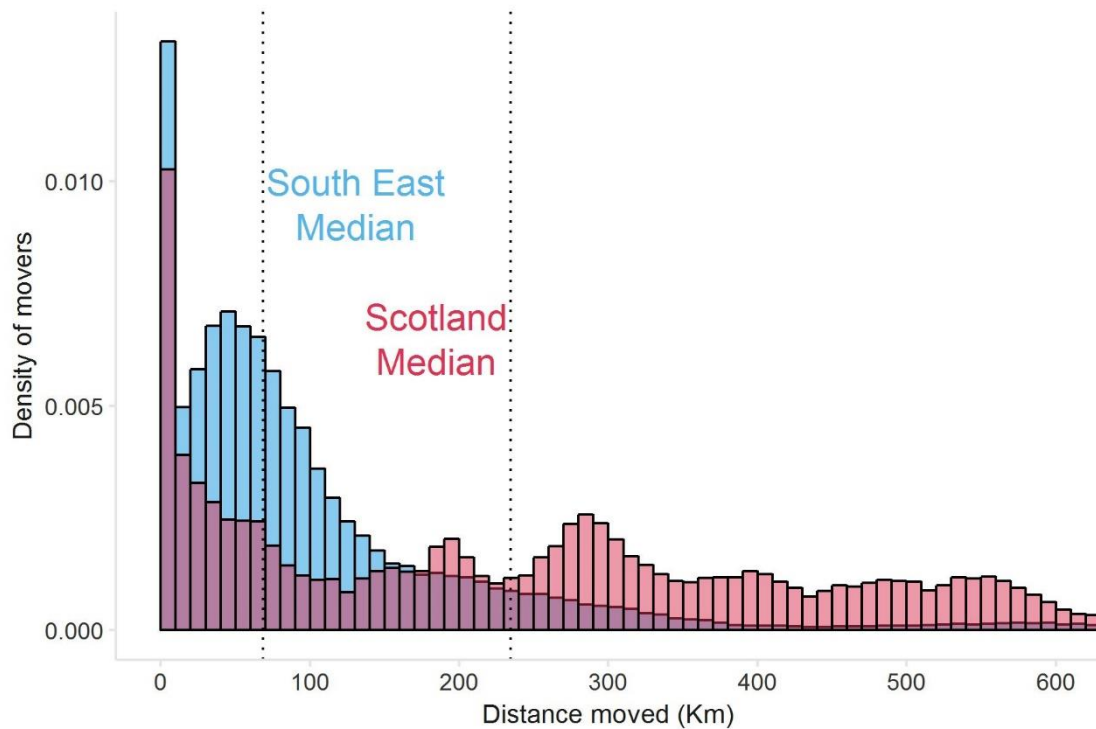
Sources: Product Sales Database and Bank calculations.

Chart 21: Distribution of house moves by distance for different ages (mortgage-to-mortgage movers in 2018, upper and lower age quartiles)
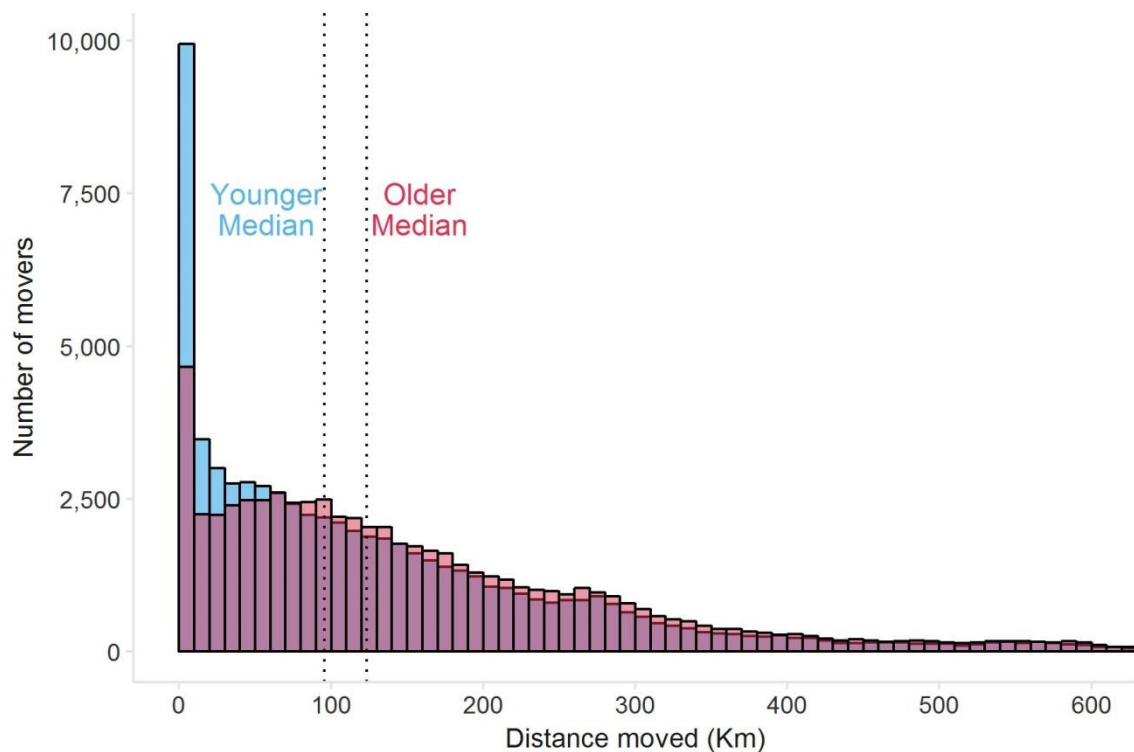
Sources: Product Sales Database and Bank calculations.

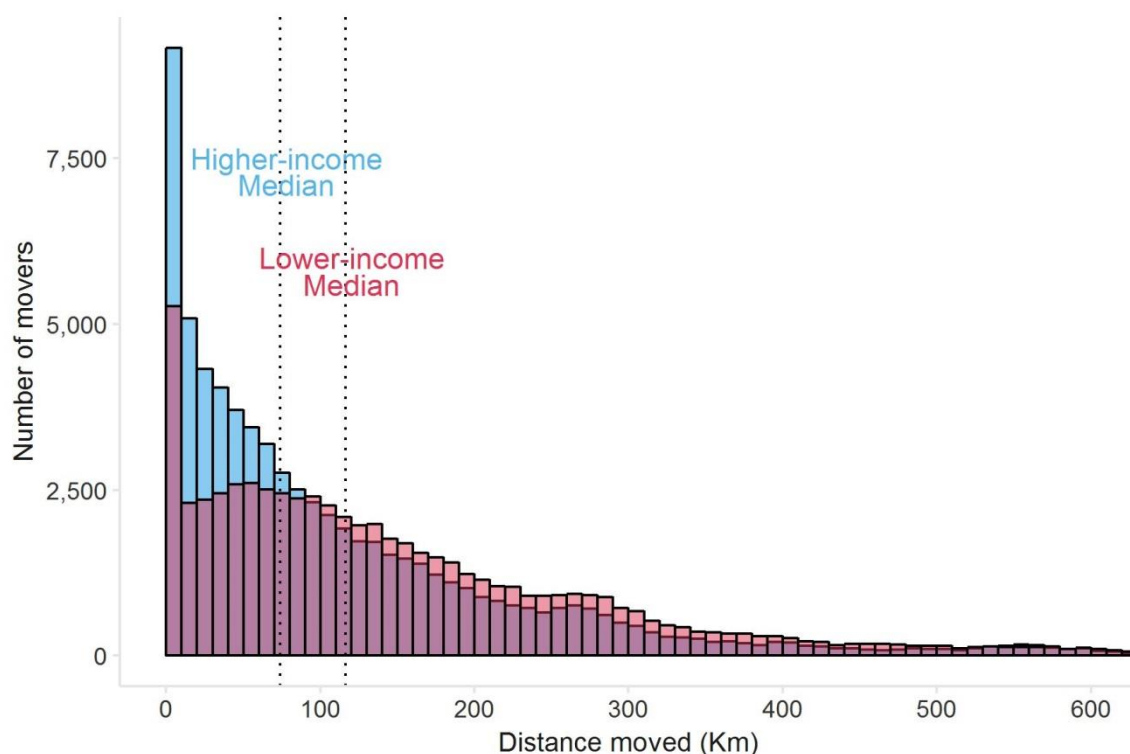**Chart 23:**   **Distribution of house moves by distance for different income groups (mortgage-and-mortgage moves in 2018, upper and lower income quartiles)**

Sources: Product Sales Database and Bank calculations.

Take Yorkshire and Humberside. A third of all moves are within-region. East, West, Home's Best. Some do move to the West (around 15%) and some to the East (7%). Although some head South-East for life in the slow lane (7%), a larger number move North to Scotland (around 10%). This only covers moves among those with a mortgage, so will not capture first-time buyers, students, renters or those retiring without a mortgage. It nonetheless offers a new lens on the housing market, locally and nationally.

It is not difficult to see how these micro-level flow data could be augmented. Data from payments systems can, and are, being used to track flows of money. Companies' management information systems can, and are, being used to track flows of workers, goods and services. And administrative data can, and are, being used to track people, money and goods. These micro-level data that could, with time, be pieced together to provide a macro – or micro-to-macro – model of the economy. Or that, at least, is the promise.

Managing the Economy

If we can map and model the economy at a high resolution how, if at all, might this affect how economic policy is set? Can analysis of this granular type help when thinking about appropriate forms of policy intervention? Might it help in defining what might be a sensible geographic area for an economic strategy? And might it even help in defining what that economic strategy might be?

There is already a deep and rich literature on these topics. One strand looks at optimal currency areas.[43] Another looks at optimal fiscal areas.[44] And a third looks at optimal political or policy areas.[45] This literature identifies a rich range of factors important for determining the optimal spatial dimension of policy. From that long list, let me highlight three factors which are commonly found to play a crucial role:

(a) Heterogeneity and Specialisation

Other things equal, the greater are the differences in the economic characteristics of an area, the stronger is the case for recognising these differences in the setting of economic policy. These economic characteristics include: the cultural and political preferences of citizens; economic fluctuations over the business cycle; and structural features of the economy, such as industrial composition and policy transmission.[46]

A related aspect is the degree of specialisation or comparative advantage in an economic area. The greater this degree of specialism or comparative advantage, the stronger the case for having it recognised and supported in the setting of economic policy. Specialisation is one of the ways in which an economic area can harvest the benefits of economies of scale and scope through the agglomeration multiplier.[47]

On the face of it, there is a considerable degree of heterogeneity across the UK, including in terms of income, wealth, health and happiness. Other things equal, this would support locally-targeted policy interventions. At the same time, those differences are often as large locally as they are regionally. That suggests a very decentralised setting of policy would be needed, which may come with costs.

(b) Diversity and Risk-Sharing

One of the most important of those costs is the loss of risk-sharing. A diverse economic area allows aggregate fluctuations to be smoothed-out, in the same way a diverse portfolio of assets smooths out returns to an investor. And by smoothing-out aggregate fluctuations, diverse economic areas can help smooth out local fluctuations by transferring resources between regions to insure against region-specific shocks.

Another set of factors weighing in the same direction are economies of scale and scope. The smaller the geographic area, the lower the potential for agglomeration effects. Some of these agglomeration benefits may themselves arise from having a diverse economic eco-system, as this enables positive spillovers between sectors and skills within an area.[48]

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[43] Mundell (1961).
[44] For example, Berger, Dell'Ariccia and Obstfeld (2018).
[45] Alesina, Tabellini and Trebbi (2017).
[46] For example, Alesina, Tabellini and Trebbi (2017), Carlino and DeFina (1996), Cumming (2018), Dow and Montagnoli (2007) and Fratantoni and Schuh (2003).
[47] Krugman (1991) and Krugman and Venables (1996).
[48] Izraeli and Murphy (2003).

(c)   Factor Mobility

A third sector of factors influencing the choice of optimal policy area concerns the degree of factor mobility. Easy movement of factors between regions can smooth-out differences between regions. For example, people moving from low to high unemployment areas can smooth out regional differences in incomes. In this way, factor mobility can serve as a risk-sharing device between areas, even without policy intervention.

The other side of this coin is that, people and money do not always flow in this direction. Factor mobility can sometimes increase, rather than smooth out, differences between regions. For example, people or firms may move to areas which offer strong existing incomes and jobs. If so, this will tend to amplify, not ameliorate, regional differences.

That is the theory. The optimal policy strategy involves balancing these factors, based on the structural characteristics of an economy, its degree of diversity versus specialism and the flows of factors within it. A digital twin of the economy, of the type outlined earlier, would embody these factors and flows and would provide a quantitative test-bed for making policy choices.

In the absence of such a model, let me discuss two examples where existing data and analytical tools could be used to inform policy choices. In line with theory, the first looks at flows of factors within a region, the second at structural economic characteristics across regions. These data and techniques can be used to shed light on policies which might boost economic growth, locally or nationally, in line with the UK Government's industrial strategy.[49]

My first example draws inspiration from recent work by Tom Forth at the Open Data Institute in Leeds, on behalf of the Productivity Insights Network (PIN) here at the University.[50] This uses data on flows of people to assess local growth prospects. The story starts with the observation that many UK cities appear to punch below their demographic weight in income terms. Put differently, a number of UK cities do not appear to benefit as much as their international counterparts from agglomeration effects.

To demonstrate, Chart 22 plots (log) city population size against GDP per head in 563 cities in advanced economies around the world, including a number of UK cities. It also shows a line of best fit. This is upward-sloping and statistically significant, consistent with agglomeration effects. Moving from a city the size of Oxford (population 535,000) to one double its size such as Sheffield (around 1.2 million) should be

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[49] Department for Business, Energy and Industrial Strategy (2017). In a personal capacity, I chair the Government's Industrial Strategy Council which evaluates its progress.
[50] Forth (2019).

expected, on average, to boost GDP per head from £27,300 per head to £28,100 per head, or around 2.6%.[51]

Chart 22: City population and GDP per head
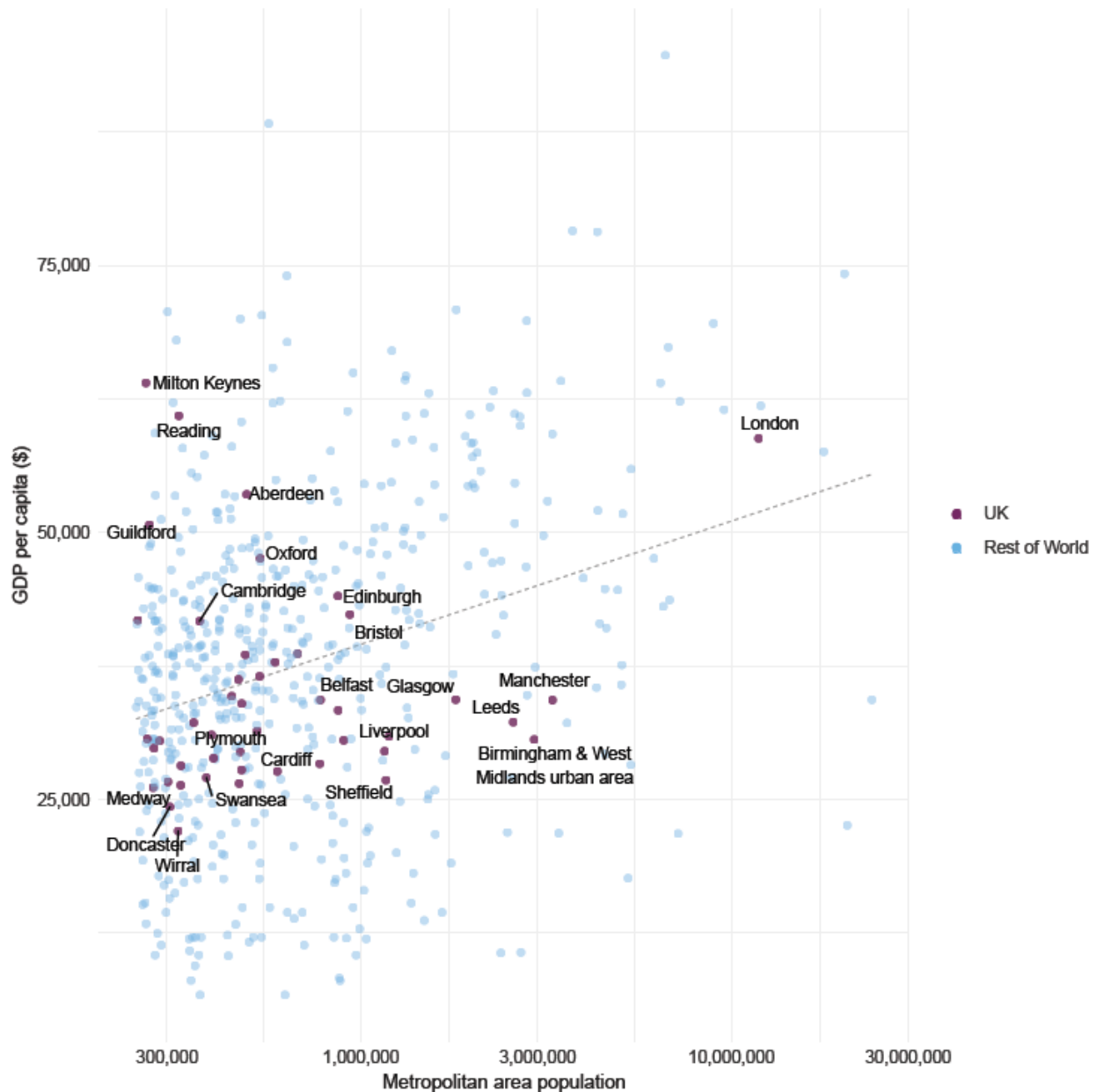
Sources: OECD Metropolitan Areas Population and Bank calculations.
Notes: GDP per capita in US$ in 2015 and log scale used for metropolitan area population.

In fact, GDP per head in Sheffield is around 44% *lower* than in Oxford. This is not just a North-South divide. Income per head in Sheffield is little different than in Doncaster just down the road (population 305,000).

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[51] Data set underlying Chart 22 refers to GDP per capita in US$ in 2015. Numbers which convert to sterling in the text are based around average $/£ bilateral exchange rate of 1.34 in 2018.

And it is not just Sheffield. Many large UK cities sit below the line: Belfast, Glasgow, Leeds, Manchester, Cardiff, Birmingham, as well as Sheffield. Agglomeration multipliers seem to be consistently smaller in a number of UK cities. Why?

Forth's work suggests transport networks are a large part of the explanation. By analysing commuting times into Birmingham at different times of the day, he provide a measure of the "effective" working population. At peak times, the effective working population of Birmingham is perhaps 50% smaller than its measured population due to poor transport infrastructure. This helps explain why Birmingham punches below its demographic weight.

This is a terrific example of how high-resolution data can be used to understand local patterns of economic growth. The same data could be used to analyse the "effective" working population in other UK cities, perhaps helping explain their under-performance. It could also be used to answer industrial strategy questions, such as what impact new transport routes have on the effective working population of the UK's major cities and hence on their incomes through agglomeration effects.

Imagine a transport strategy whose aim was to raise the effective working population of those UK cities currently operating below the line. Using Chart 22, doing so would raise UK GDP per head by around 10% or around $4,100 (£3,100) in today's money. Those annual benefits could be compared with the one-off costs of investment to determine the desirability of such a policy, as part of the UK's industrial strategy.

My second example draws inspiration from recent work at the University of Cambridge by Penny Mealy, including by my colleague on the Industrial Strategy Council Diane Coyle.[52] This looks at the structural economic characteristics of different regions and provides a way of summarising and ranking them. The particular way it does so is by measuring their "economic complexity", following the work of Hidalgo and Hausmann (2009) in the context of international trade.

Without going into the technicalities, the complexity index can loosely be thought of as weighing the two structural characteristics of an economic area which theory would suggest are crucial for economic success. The first is the degree of *specialism* or comparative advantage in a particular product or industry: the greater this specialism, the greater an area's complexity. The second is the degree of *diversity* in this specialism across products and industries: the greater this diversity, the greater an area's complexity.[53]

Though the construction of an Economic Complexity Index (ECI) is itself complex, the principles underlying it are not. An economic area exhibits complexity when it has a diverse set of highly-specialised industries. An

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[52] Mealy and Coyle (2019).
[53] This description sets out a stylised interpretation of ECIs as they were originally conceived by Hidalgo and Hausmann (2009). Recent work by Mealy, Farmer and Teytelboyn (2019), however, has re-assessed the interpretation of ECIs and found that diversity is mathematically orthogonal to ECIs. In this new interpretation, ECIs instead provide a useful way to understand place-based similarly in industrial specialisations.

area lacking complexity has few or no industries or products which are specialised. ECIs have been constructed at the nation-state level and, more recently, at the local level in the US and UK.[54]

One of the interesting features of these empirical ECIs is that they appear to match the theory: the greater the degree of specialisation and diversity, and the higher the ECI, the better the economic outcome. One rationale for this finding, proposed by Hidalgo and Hausmann, is that ECIs serve as a proxy of the degree of knowledge embedded in an economic area, knowledge that comes courtesy of specialisation and diversity.

Charts 23 and 24 plot local authority level ECIs against measures of income per head and hourly earnings in the UK. They show a positive, statistically significant relationship. The same has been found at national level and among US states. The embodied-knowledge effect is, on the face of it, an empirically strong one. In a bivariate regression, ECIs account for around half of the regional variation in level of incomes and pay.

Chart 23: Local authority-level ECIs and income per head
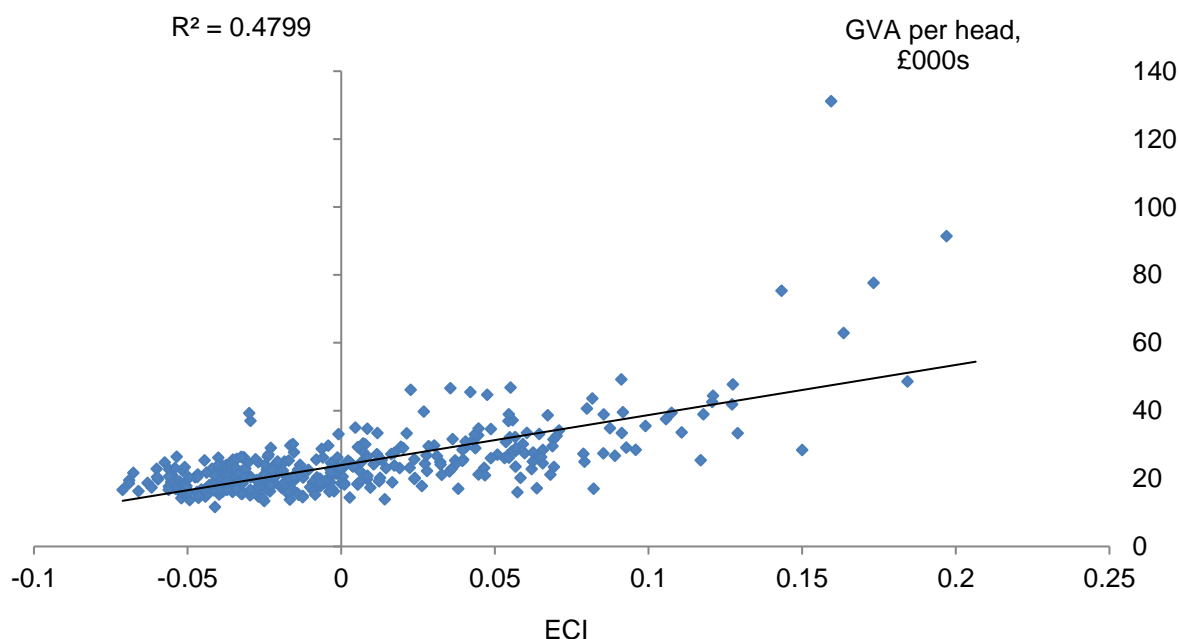
Sources: ONS Regional Gross Value-Added, ONS Business Register and Employment Survey (BRES) and Bank calculations.
Notes: ONS regional gross value-added (balanced) by local authority in the UK for 2016 against economic complexity indices calculated using BRES. City of London and Westminster excluded from chart.

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[54] Hidalgo and Hausmann (2009) for international comparisons and Mealy, Farmer and Teytelboym (2019) for regional comparisons.

Chart 24: Local authority-level ECIs and hourly earnings

Hourly earnings,
£ per hour

R² = 0.4466

ECI
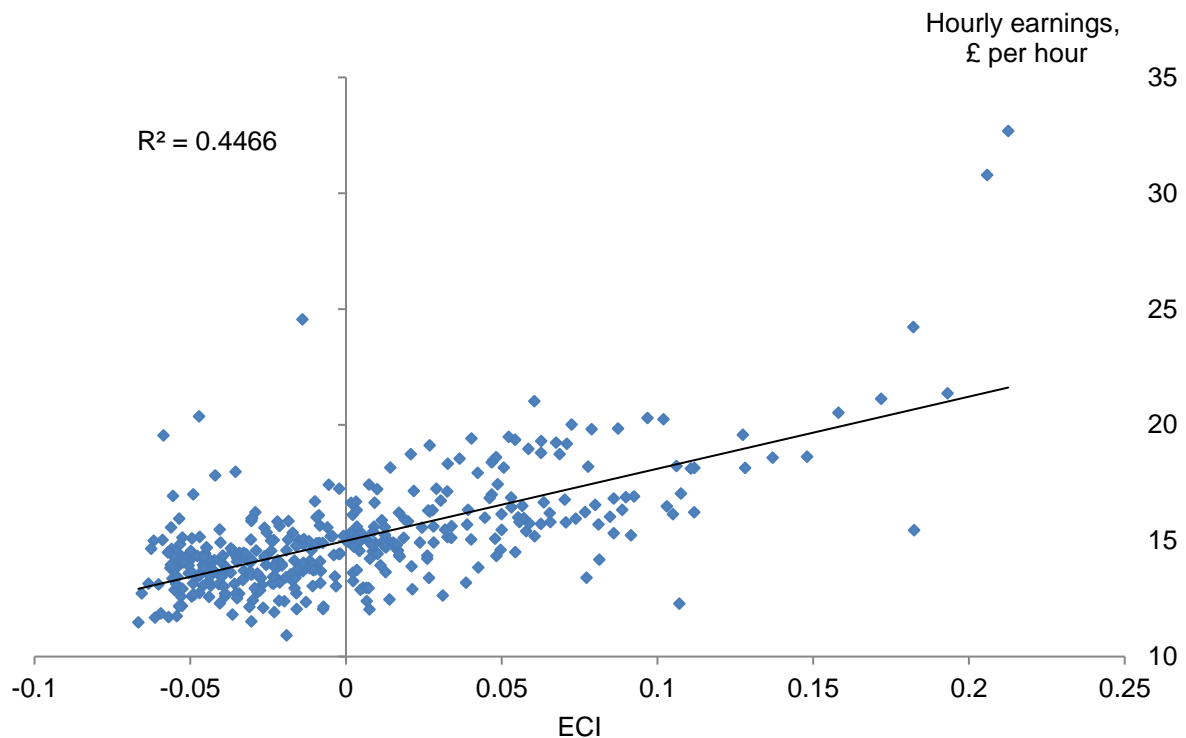
Sources: ONS Annual Survey of Hours and Earnings (ASHE), ONS Business Register and Employment Survey (BRES) and Bank calculations.
Notes: Data available for Great Britain only (i.e. excluding Northern Ireland). Mean hourly earnings excluding overtime against economic complexity indices calculated using BRES.

Chart 25 plots a cartogram of local authority level ECIs for the UK, at the NUTS 3 level. It shows a remarkable degree of difference across areas of the UK. This matches regional differences in income and pay. These metrics could help when designing the Local Industrial Strategies currently being developed by Local Enterprise Partnerships (LEPs) and the devolved nations in Scotland, Wales and Northern Ireland.

Table 1: Top 10 local authorities by ECI

City of London	Camden
Tower Hamlets	Hammersmith & Fulham
Southwark	Kensington & Chelsea
Westminster	Hackney
Islington	Cambridge

Sources: ONS Business Register and Employment Survey (BRES) and Bank calculations.

Chart 25: Cartogram of local-authority level ECIs

Glasgow City

Edinburgh, City Of

Leeds

Greater Manchester South

Liverpool

Sheffield

Nottingham

Solihull

Outer London – West And North West

Inner London – East

Cardiff And Vale Of Glamorgan

Swindon

Inner London – West

Bristol, City Of

Berkshire

Surrey

Outer London – South

Southampton

Brighton And Hove

ECI
-0.1 0.0 0.1 0.2 0.3
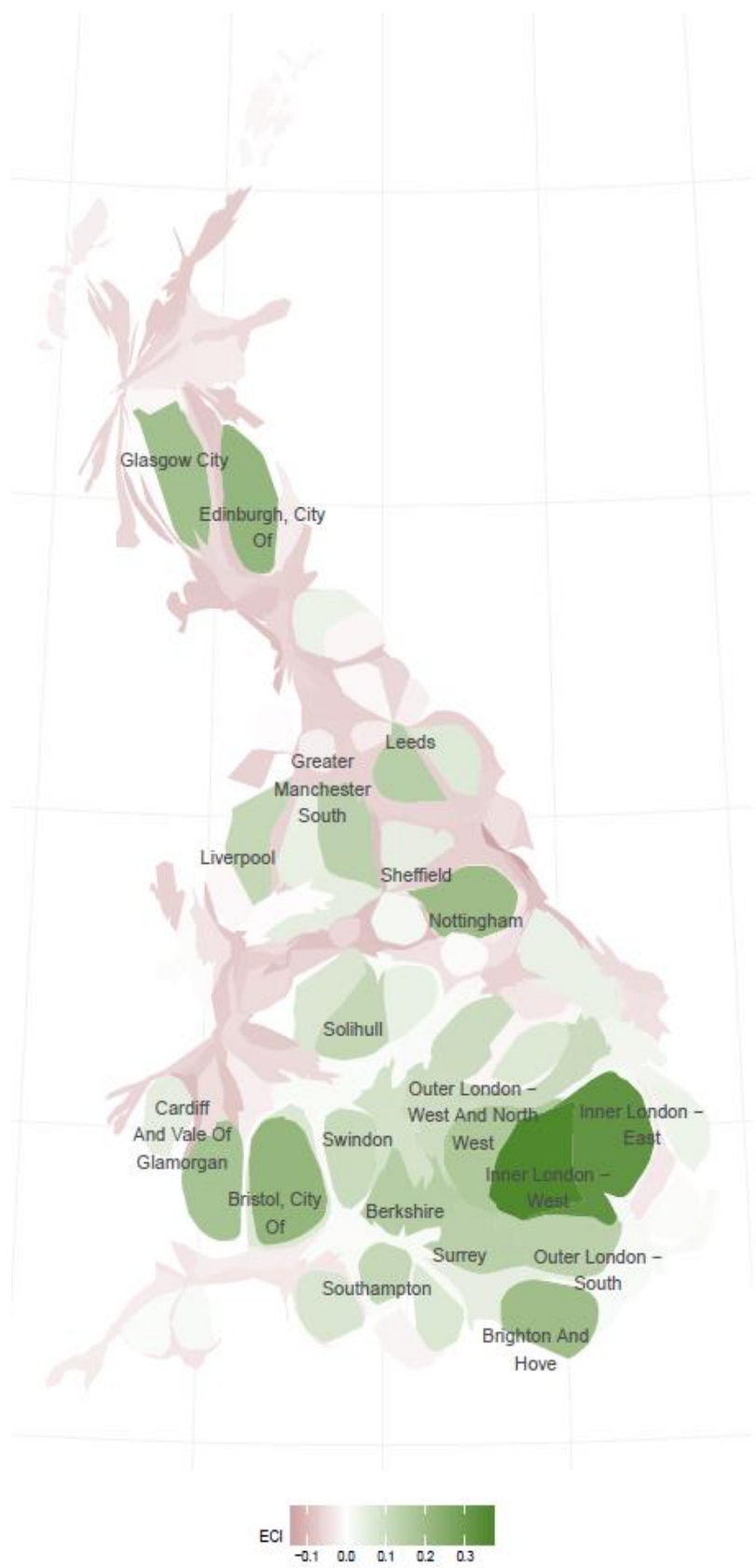
Sources: ONS Business Register and Employment Survey (BRES) and Bank calculations.
Notes: UK NUTS 3 regions re-sized and coloured using estimates of economic complexity.

Table 1 lists the top ten local authorities by ECI across the UK in 2017, while Table 2 shows the bottom ten. There is a high degree of inertia in both rankings. The ECI framework could be used to help assess which industrial strategy interventions might boost the degree of specialism and diversity, and hence the income benefits, both in already-successful and struggling regions.

Table 2: Bottom 10 local authorities by ECI

Dudley	Moray
South Derbyshire	Hartlepool
Wrexham	Carmarthenshire
Aberdeenshire	Breckland
North-East Lincolnshire	Telford and Wrekin

Sources: ONS Business Register and Employment Survey (BRES) and Bank calculations.

Economic complexity can also be assessed across industries using a product complexity index (PCI). This proxies the embedded knowledge in an industry. Table 3 plots the top-20 UK industries by PCI against their sector shares. Financial services, the creative industries, and higher education exhibit the highest economic complexity and thus potentially generate the highest value-added. PCI metrics could be used to identify industries where "sector deals" could benefit most the economy, as part of an industrial strategy.

Table 3: Top 20 UK industries by PCI and share of employment

Reinsurance	0.01%
Fund management activities	0.16%
Television programming and broadcasting activities	0.08%
Trusts, funds and similar financial entities	0.03%
Motion picture, video & television programme activities	0.34%
Sound recording and music publishing activities	0.03%
Legal activities	1.09%
Translation and interpretation activities	0.02%
Software publishing	0.04%
Creative, arts and entertainment activities	0.32%
Activities auxiliary to financial services, except insurance and pension funding	0.66%

Publishing of books, periodicals and other publishing activities	0.35%
Accounting, bookkeeping and auditing activities; tax consultancy	1.29%
Advertising	0.42%
Computer programming, consultancy and related activities	2.43%
Leasing of intellectual property and similar products, except copyrighted works	0.01%
Market research and public opinion polling	0.14%
Organisation of conventions and trade shows	0.08%
Higher education	1.61%

Sources: ONS Business Register and Employment Survey (BRES).
Notes: Dates for 2017. Only industries with 1000+ employees included in table.

These are partial, though informative, pieces of micro-level evidence, though no substitute for an economy-wide digital twin. This could be used as a general equilibrium test-bed for formulating, and evaluating the impact, of industrial strategy interventions, nationally and locally. Those policy simulations could be complemented by controlled trials of policies, the like of which have been successfully pioneered by the What Works Centre for Local Economic Growth.[55]

The economy is a complex, adaptive system. Behaviour in those systems is difficult to predict ex-ante, especially at times of policy change; it is emergent, just as a hurricane or tornado is emergent. Often, our policy intuition about complex systems is simply wrong. No model, however micro-founded or data-rich, is proof against those uncertainties. But one that embodies complex, micro-level dynamics is more likely to do so than one without them. A complex systems framework can make for robust policy choice.

That was Jay Wright Forrester's insight in the 1950s. We know it to be true from more recent experience. The real-time, supply-chain data system developed by Walmart twenty years ago transformed inventory management, at Walmart and elsewhere. The real-time micro-level models developed by meteorologists transformed weather-forecasting at around the same time. Today, digital twinning is transforming processes across companies. These are microcosms of what might be achievable at the macroscopic scale.

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[55] For example, What Works Centre for Local Economic Growth (2018).

Can a Central Bank be Local?

Finally, what are the implications of these local economic perspectives for central bank policy? On the face of it, these might seem few. Central banks are national agencies. Their policies, such as interest rates, can only be set at the national level. It is impossible for the Bank of England to set separate interest rates for Aberdeen and Aberystwyth, Belfast and Birmingham. A central bank, by definition, cannot be local.

Or can it? I would argue that not only is this feasible but essential. I have spoken previously about the "twin deficit" problem facing central banks: the deficit in public *understanding* and the deficit in public *trust*.[56] Boosting this understanding, and restoring trust, among the public is among the most pressing issues facing central banks. Reconnecting communities with institutions helps strengthen Rajan's Third Pillar.

But how is this best done? The public's understanding of the economy and policy is enhanced when messages are relevant to their lives and locality.[57] A central bank's understanding of the economy is enhanced if it can tap into the lived, local experiences of companies and citizens making up the economy. And a better mutual understanding between communities and central banks would, in turn, help build trust between them. Constructing a Third Pillar shrinks the twin deficits of public trust and understanding.

This is not a new point. Despite being headquartered in London since 1694, the Bank of England has had a regional presence for much of its history. After the UK banking crisis of 1825, the Bank set up a network of 15 regional branches to provide commercial banking facilities.[58] Though their purpose was operational, it quickly became clear that the intelligence gathered by the Bank's branches could help in understanding the economy. This intelligence was soon being fed back to Head Office.

During the 20th century, this intelligence-gathering role was expanded. It has grown steadily, in scale and importance, since then. Today, the Bank's 12 Agencies across the UK have around 9,000 regular company contacts providing real-time intelligence on the economy. Structured surveys from the Agents first appeared in 1997. Agents' National Scores were first introduced in the mid-1990s and first published in 2006. Agent's Company Visit Scores were first developed in 2007 and first published in 2015. [59]

Brexit provides as good an illustration as any of the ways the Agents' high-frequency, high-resolution intelligence can improve the Bank's understanding of the economy. A key question recently has been whether and how companies have been preparing for Brexit.[60] The Agents' network was used not only to track how prepared companies were over time, but what form this contingency planning was taking – stock-building, seeking alternative suppliers, building cash reserves *etc* (Chart 26).
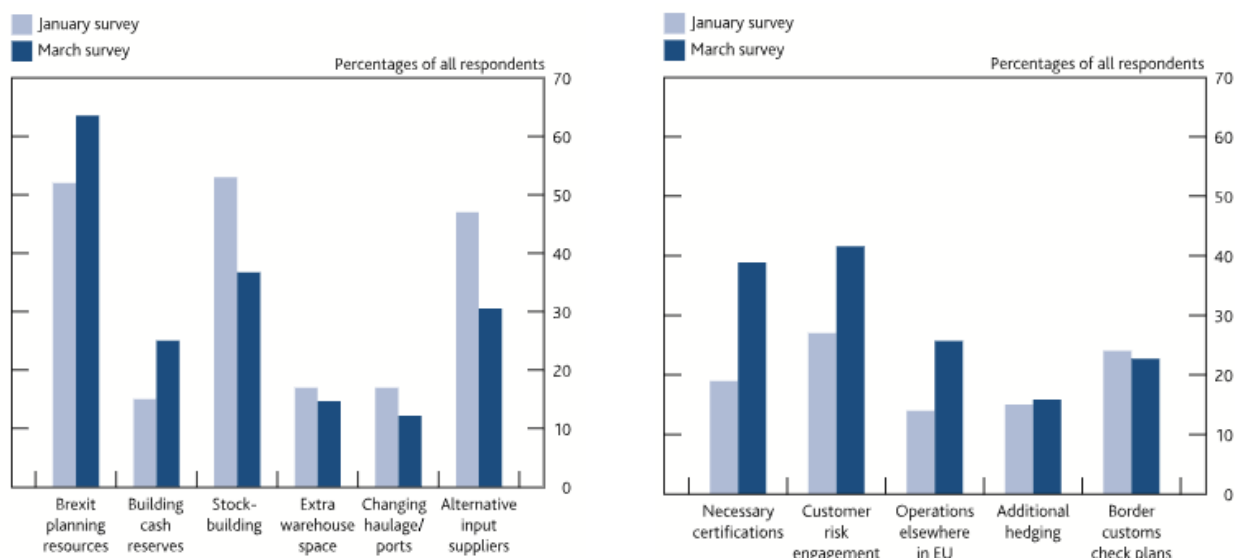
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[56] Haldane (2017).
[57] For example, Agerström et al (2016).
[58] Bank of England (1963).
[59] Ellis and Pike (2005).
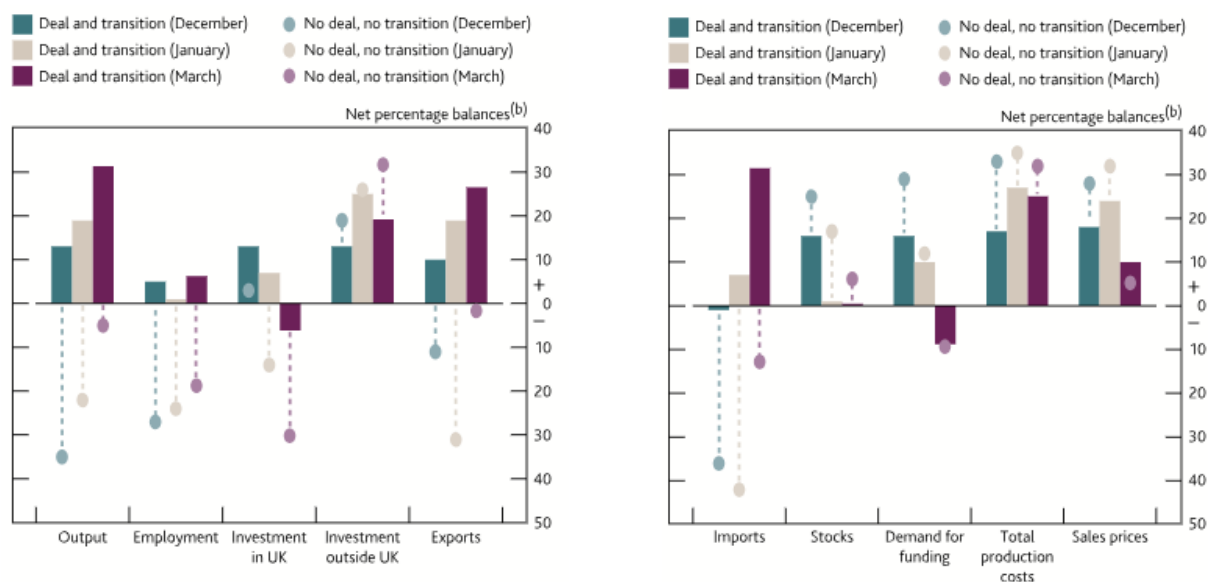[60] Bank of England (2019).

Chart 26: Contingency planning by firms for Brexit

Sources: Bank of England and Bank calculations.

Company contacts also helped the Bank's Brexit scenario planning. Companies were asked about the consequences for their businesses of a "no deal, no transition" Brexit. The results are shown in Chart 27. They suggest a marked slowing in output, employment and investment under this scenario, consistent with the Bank's in-house macro-economic models. This is micro-to-macro in practice.

Chart 27: Firms' expectations for economy under a no-deal, no-transition Brexit

Sources: Bank of England and Bank calculations.

Recently, the Bank has used its regional network to augment its local engagement. Two years ago, I began a programme of "Townhall" visits to some of the UK's most poorly-performing regions, often organised in conjunction with local charities, faith or community groups including Age UK, Citizens' Advice, the Board of

Deputies of British Jews, the Muslim Council of Britain, Oxfam and the YMCA. These Townhalls engage the public directly on issues around the economy and finance. They, too, are a micro-to-macro approach.

So far, I have undertaken 14 Townhall visits covering all parts of the UK.[61] They are a direct conversation between the Bank and the public, typically on local economic and financial issues. They draw on the sorts of listening and facilitation techniques more familiar from anthropology and sociology. Intelligence-gathering means extracting economic narratives, rather than facts, about the forces shaping people's lives and decisions. The anthropologist Clifford Geertz calls this approach "deep hanging out".[62]

Deep hanging out is harder than it sounds. A day's talking leaves me tired. A day's listening leaves me exhausted. Entering a room as the least knowledgeable person, at least on local issues, can be a culture shock. But it is those very things that make intelligence from the Townhalls distinctive and valuable. Statistical surveys cannot capture narrative in a way conversations can. The Townhall visits have been one of the most enlightening things I have done in my almost 30 years at the Bank of England.

The Bank has recently expanded and deepened its range of local initiatives. One of these is Citizens' Panels.[63] After a couple of trials last year, the Bank recently began rolling-out Citizens' Panels across each of its regional agencies. These panels have an independent external chair, drawn from the local region, to facilitate discussion. Each is attended by a senior Bank policymaker. Messages from the panels will be drawn together periodically and published externally.

Complementing Citizens' Panels, the Bank's direct engagement with community groups is now being expanded through a set of "Community Forums", working in partnership with local charities and community groups. The Governor recently launched these forums with events in Tower Hamlets and Glasgow. Other Governors and Directors have their own Community Forums planned through this year and beyond.

The Bank's education programme also has strong local presence. The educational materials developed by the Bank for 11-16 year olds, econoME, have been taken up by a third of schools across the UK. Last year, staff ambassadors visited close to 300 schools across the UK to deliver talks on the economy and economic policy. These are examples of a central bank acting locally.

Central banks around the world seem themselves to be moving in this same direction, with greater local, citizen-level engagement. Other central banks to have recently launched community-based initiatives include the US Federal Reserve's "*Fed Listens*" events. These involve roundtables with the general public, involving local leaders, policy experts and academics from across the United States.[64]

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[61] https://www.bankofengland.co.uk/outreach
[62] Geertz (1998).
[63] Patel, Gibbon and Greenham (2018) and Haldane (2018b).
[64] https://www.federalreserve.gov/monetarypolicy/review-of-monetary-policy-strategy-tools-and-communications-fed-listens-events.htm

These initiatives are a good foundation for central banks, for constructing a Third Pillar. More of these types of local, citizen-based engagements may be needed in the years ahead, if policy institutions are to shrink the twin deficits and strengthen that Third Pillar. There is scope to decentralise more of central banks' activities, giving them greater reach, voice and engagement locally. That would certainly get my personal vote.

Conclusion

Our economies, like our politics, are local. Like the seashore, the more you magnify an economy, the greater its richness, complexity, self-similarity. Like our bodies, understanding our economic health means taking readings at many resolutions. It means understanding the moving body parts, and their interactions, in microscopic detail. It calls for new data, at a higher frequency and higher resolution, and new ways of stitching it together. It means making micro-to-macro a reality.

Our global weather systems, oceans, information networks, supply chains, solar system, galaxies and even our universe can these days be mapped and modelled in microscopic detail in close to real time. We cannot yet do so for our economies. I believe our economic policies would be better able to serve the public, and better understood by them, if we could do so.

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