Supporting Information for:
Global trends towards urban street-network sprawl

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A Urban development time series

The majority of our analysis employs the time series from GHSL, an open-data project providing global spatial information about the human presence on the planet over time [Pesaresi et al., 2013]. Data are available online (http://ghsl.jrc.ec.europa.eu). We use the built-up grid which is derived from analysis of Landsat image collections, and provides built-up year classifications with approximately 38 m resolution. Pixels are classified as follows: land not built-up in any epoch; built-up from 2000 to 2014 epochs; built-up from 1990 to 1999 epochs; built-up from 1975 to 1989 epochs; built-up before 1975 epoch. For computational reasons, we aggregate to 306 m resolution, and calculate the built-up year of the aggregated grid cells as the modal built-up year of individual pixels. Each edge and node is assigned the modal epoch of the intersecting pixels.

Our city-level aggregations utilize the time series from Atlas of Urban Expansion [Angel et al., 2012, 2016], an open-data online database of city boundaries. The Atlas includes a sample of 200 of the world's metropolitan areas that had 100,000 people or more in 2010 and provides urban extents at three time points: circa 1990, circa 2000, and circa 2013. We calculate spatial differences between successive time points in order to generate boundaries for new development during the periods 1990–1999 and 2000–2013. We then aggregate our street-level metrics to these regions to characterize development over time in these cities.

Below, we analyze the consistency of the development dates from each source, through comparing them to each other, and to our earlier work in the USA. Figure S1 shows the consistency of our two data sources where they overlap. The GHSL dataset tends to assign an earlier year-built to each node, but the trends are consistent.

For the USA, we also compare the GHSL-based method of generating a time series to our earlier work, which used census and county parcel assessment data [Barrington-Leigh and Millard-Ball, 2015]. The census-based method covers the entire USA and assigns to each block group households' median report of the year when their house was constructed. The parcel-based method covers only about a third of the USA but makes use of county records' building construction date for every residential property in order to assign an original construction date for each street segment. As shown in Figure S2, the methods assign closely matching dates to road segments, even though the data sources are completely independent: one relies solely on remote sensing data, while the others rely on self-reported house construction dates. For years through 1999, the inter-quartile range of the census- and parcel-data methods matches GHSL almost exactly. For the most recent period (2000-13), while the median years align (solid red lines), the inter-quartile range does not fully overlap. This is likely due to aggregation bias in census geography, as the block group boundaries do not reflect more recent development.

Consistency in the time series of road network evolution translates into consistency in our main results, which concern the evolution of connectivity over time. Figure S3 presents comparisons of trends in mean degree and fraction of deadends, the two metrics used to characterize sprawl by Barrington-Leigh and Millard-Ball [2015], for the entire USA and for one metropolitan region with good coverage by parcel-based data.

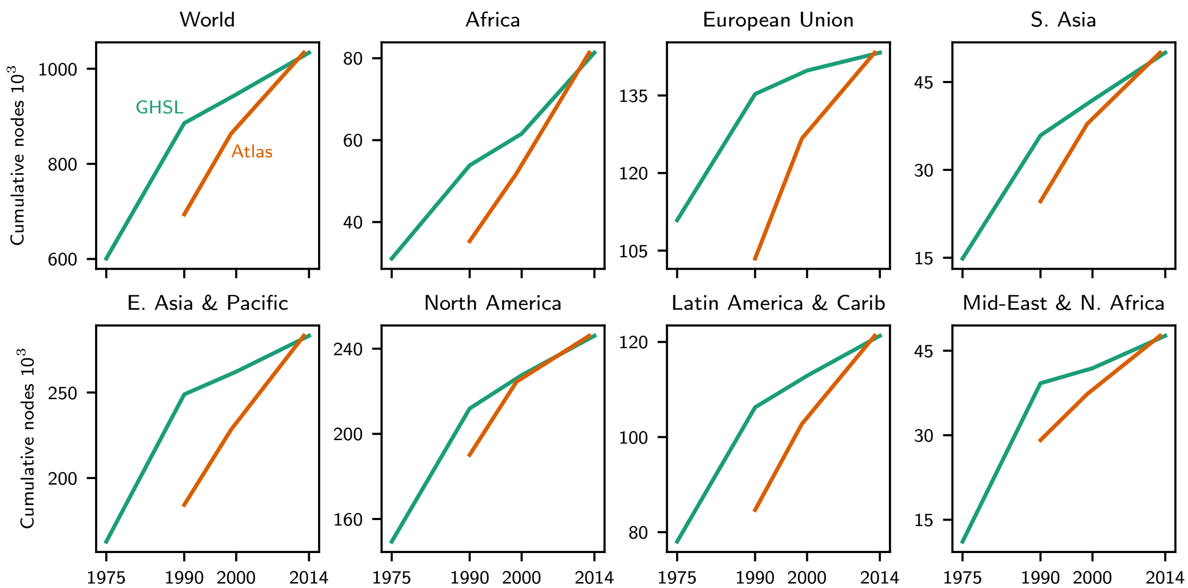

Figure S1: **Comparison of GHSL and Atlas.** Each plot shows the cumulative number of nodes within the Atlas cities, for the entire world and by select World Bank-defined regions. By construction, the cumulative number is equal in 2014.

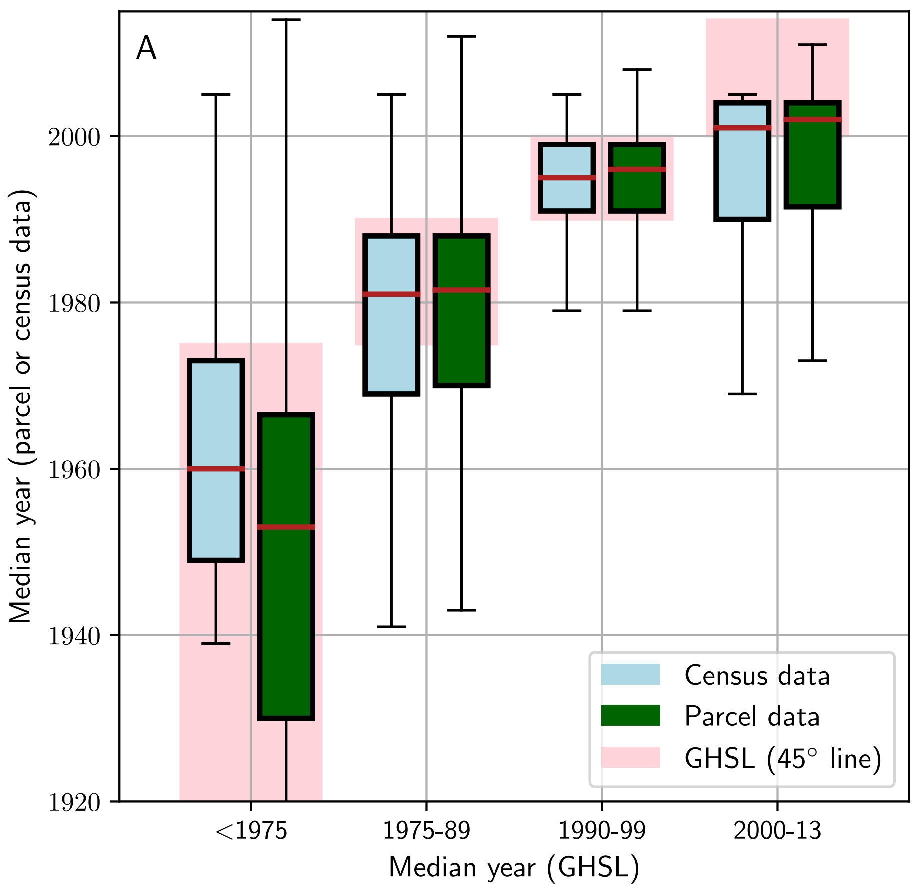

Figure S2: **Comparison of GHSL with parcel- and census-based measures, USA.** The units of analysis are census block groups in urban areas. We take the median GHSL year of each node with a block group, and compare that to the median year built of residential units within the block group ("census data"), and the median year of nodes within the block group, calculated from parcel assessment data on construction years ("parcel data"). Note that the census data have complete coverage, while the parcel-data sample accounts for about one-third of the urban US [Barrington-Leigh and Millard-Ball, 2015].

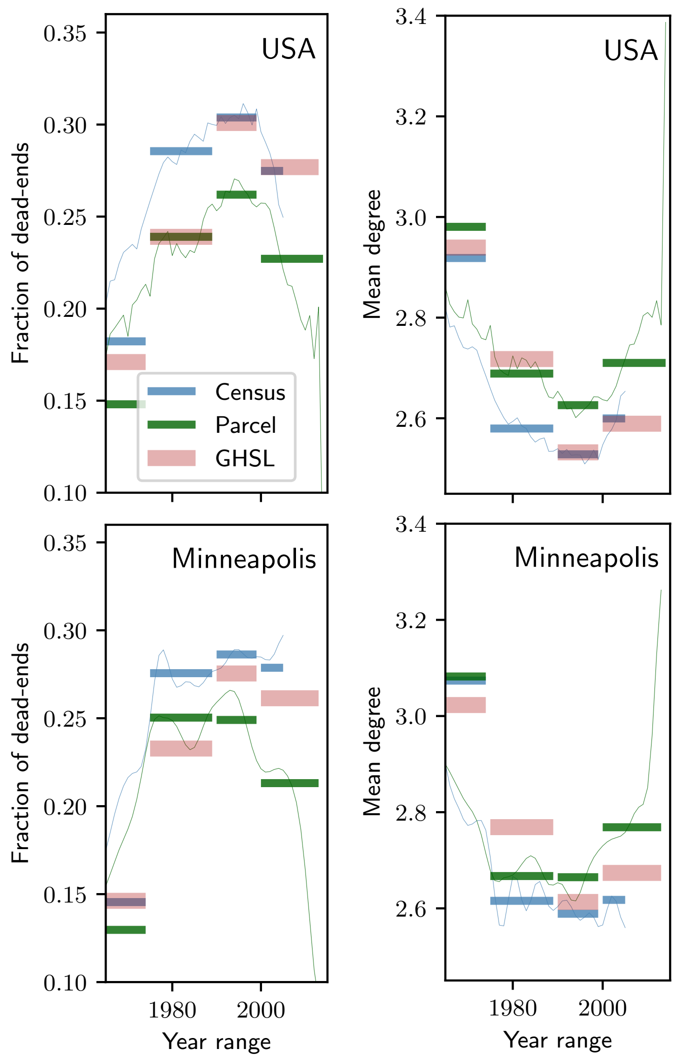

Figure S3: **Validation of connectivity time series, using house construction dates**. The time series of street-network sprawl (measured by the fraction of deadends) in our earlier work [Barrington-Leigh and Millard-Ball, 2015] is consistent with that generated by the remote-sensing method (GHSL) used in our global analysis. We show two connectivity measures calculated for the urban USA in our earlier work (top plots), as well as for the metropolitan area (Minneapolis-St Paul) where tax parcel data have the greatest coverage. For parcel and census data, thin lines show yearly averages (smoothed in the case of Minneapolis) while bars show period averages for comparison with GHSL. The first period average is the stock value up to 1974.

B Persistence

The main text discusses the persistence of street-network sprawl. Figure S4 repeats a figure from the main text, but provides small, zoomable labels.

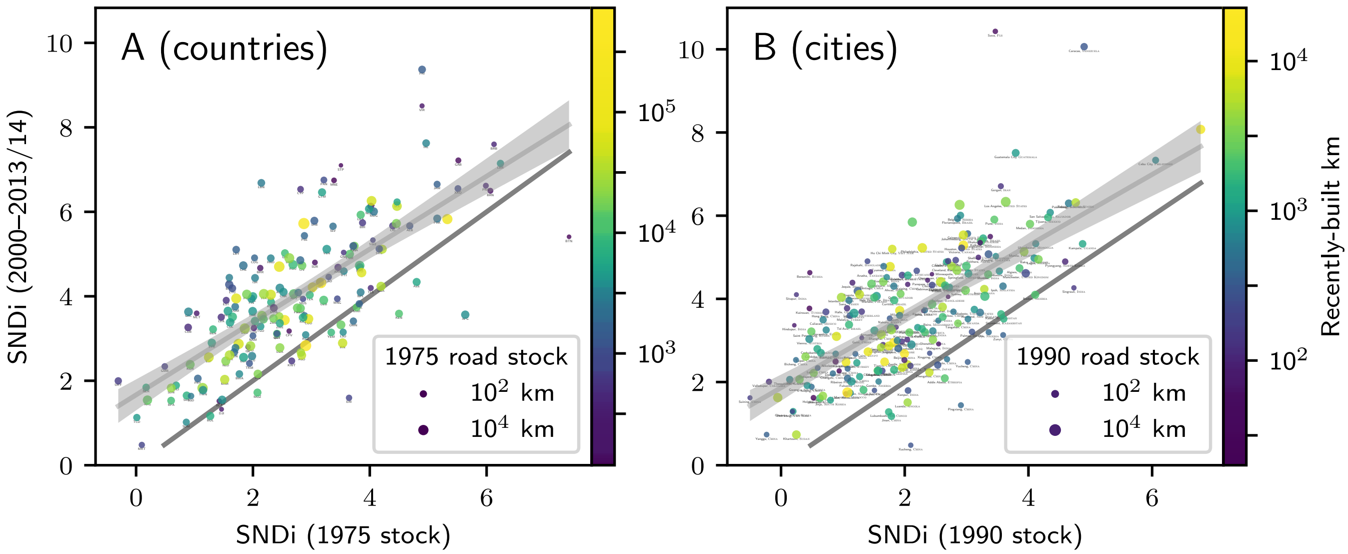

Figure S4: **Path dependence in street-network sprawl**. This figure is repeated from the main text, with the addition of small labels on cities and countries (three-letter ISO) visible by zooming in. SNDi of recent (2000–2013) construction is closely correlated with that of the earlier road stock in 1975 (countries, A) and 1990 (cities, B). Circle size denotes the length of original road stock, while color indicates the scale of recent construction. Only cities and countries with at least 100 km of new roads are shown. Linear fits characterizing the persistence relationship (gray shaded confidence region) are nearly parallel to the 45 degree line of perfect persistence (dark grey line) indicating a relatively uniform shift (on average ΔSNDi = +1.56 for cities, +1.26 for countries) away from earlier high connectivity.

C Sensitivity analysis

C.1 Inclusion of non-urban roads

While our preferred metrics are based only on the portions of road network we classify as urban, which account for 75% of nodes and 77% of edges (see Barrington-Leigh and Millard-Ball [2019] for details), we also calculate all measures on the full global set of nodes and metrics. Figure S5 and Figure S6 (top-right panels) compare this analysis to the corresponding figures from the main text (top-left panels), and show that including the remaining non-urban nodes and edges makes no qualitative, and only subtle quantitative, differences. There is a small rightward shift in the distribution of SNDi, shown in the inset to Figure S5, particularly in Russia and some countries in northern South America, indicating that non-urban streets tend to be less connected. The qualitative conclusions, however, are unchanged.

C.2 Buffer radius used to separate nodes/junctions

We reran our entire analysis using a radius of 7 m for merging intersections into nodes in our network representation (lower-left panels in Figure S5 and Figure S6). Aggregate findings are nearly identical to the 10 m version used in our primary analysis.

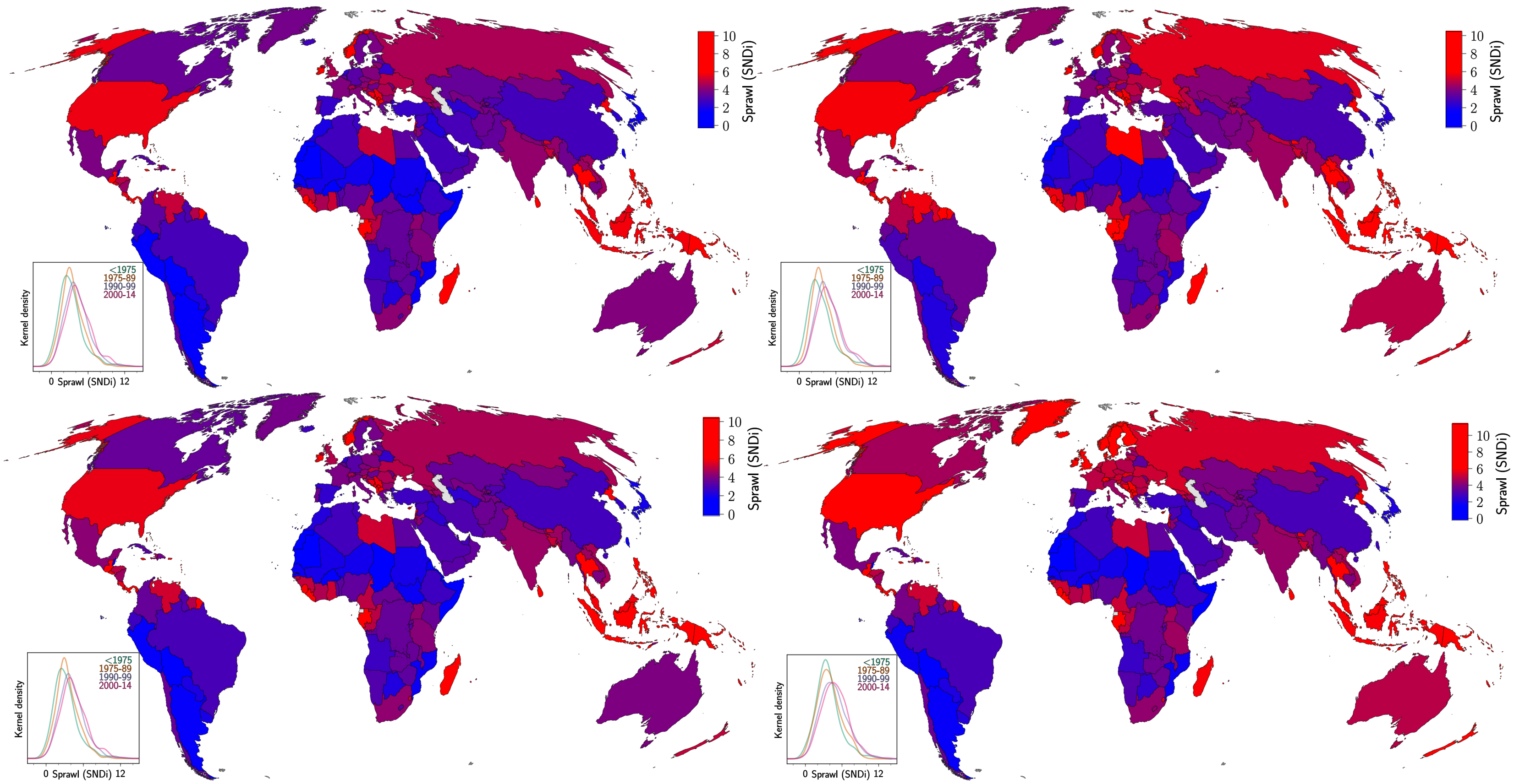

Figure S5: **Sensitivity analysis for Figure 1 from the main text**. The top-left map reproduces Figure 1, recent SNDi, from the main text. At top-right is a version calculated using all (i.e., urban and non-urban) nodes and edges, rather than only those we designate as "urban." The lower left map is a version calculated with an alternative intersection buffer radius (7 m), and the lower right one is calculated with the exclusion of walking and bicycling paths and service roads.

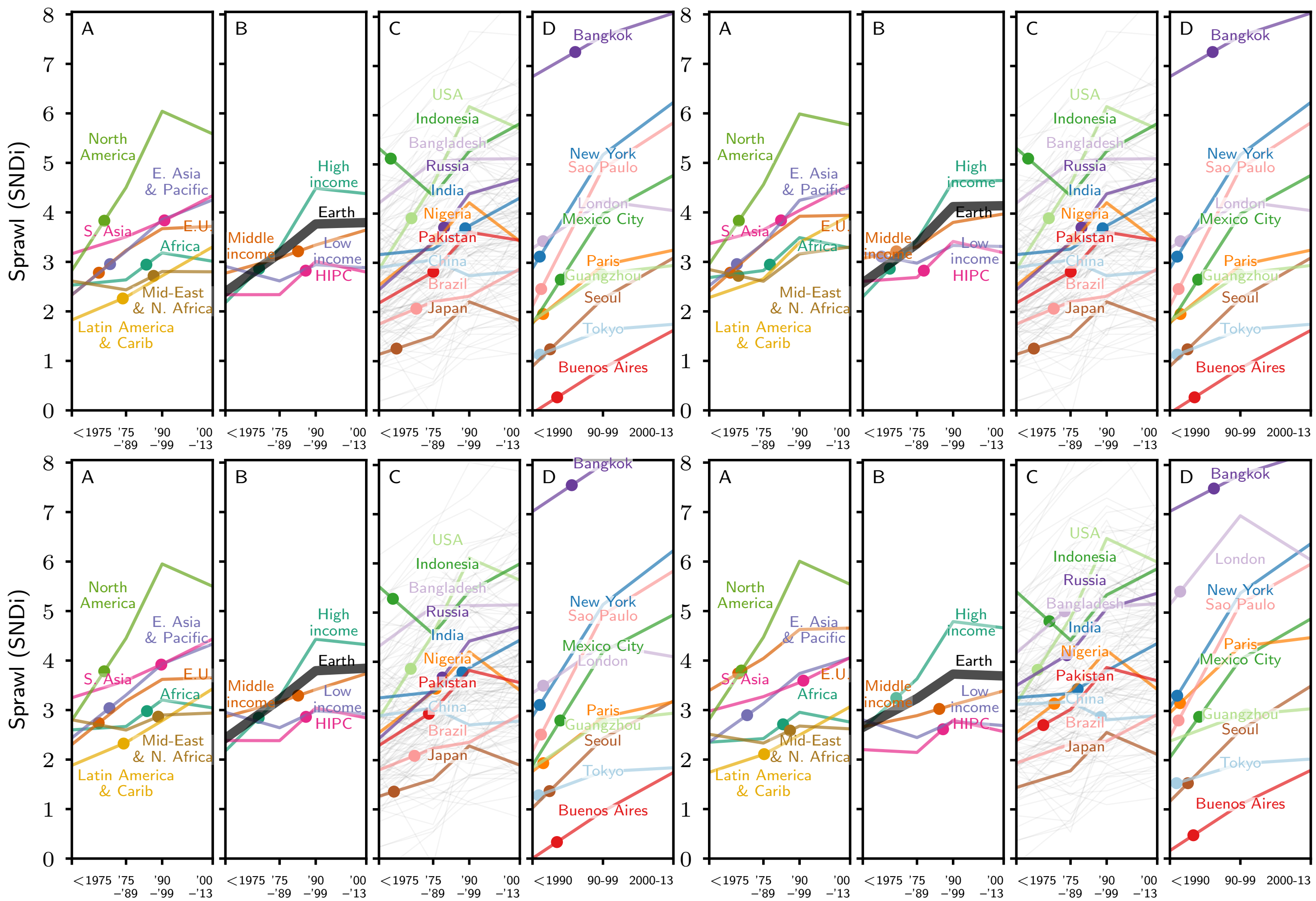

Figure S6: Top left: **Sensitivity analysis for Figure 2 from the main text**. The top-left set of panels reproduces Figure 2, trends in SNDi, from the main text. At top-right is a version calculated using all (i.e., urban and non-urban) nodes and edges, rather than only those we designate as "urban." The lower left panels are a version calculated with an alternative intersection buffer radius (7 m), and the lower right set are calculated with the exclusion of walking and bicycling paths and service roads. In each panel, the left two sub-plots share an ordinate scale, and the right two share a separate ordinate scale.

C.3 Exclusion of walking and cycling paths

Our main results aggregate the properties of only those edges and nodes that are accessible by motor vehicle. However, walking and cycling paths, as well as service roads such as driveways, are considered when calculating connectivity. For example, two adjacent culs-de-sac that are connected by a pedestrian path would not be considered deadends. (See Barrington-Leigh and Millard-Ball [2019] for details.) Figure S5 and Figure S6 (lower-right panels) show the results of an analysis that excludes all walking and cycling paths and driveways. Several countries and cities, particularly in the UK, Scandinavia and other parts of Europe, show substantially higher SNDi when the extra paths are completely excluded, indicating that such paths make a major contribution to the connectivity of the street network. The increase in SNDi in London is particularly marked. The discussion in the main text elaborates on the implications for policy.

D Data and code release

All data used for this work are open. Freely available sources are listed under "Data Release" in Barrington-Leigh and Millard-Ball [2019] and in the Materials and Methods section of the main text. Our code to reproduce the data and analysis, which itself leverages exclusively open-source tools, is released under the GNU General Public License v3.0 as an open source project, permanently available at:

`https://alum.mit.edu/www/cpbl/publications/2020-PNAS-sprawl/code`

That site includes the following description of the code:
`https://gitlab.com/cpbl/global-sprawl-2020/blob/master/README.md`

In addition, we provide the data corresponding to our street-network sprawl metrics aggregated to various levels described in more detail in Barrington-Leigh and Millard-Ball [2019]. Data are served from the following site:
`https://alum.mit.edu/www/cpbl/publications/2020-PNAS-sprawl/data`

Moreover, an interactive map interface to our high-resolution results, with links to data downloads, is available at https://sprawlmap.org.

E Citation and contact

For any use of the data or code, please cite the main paper.

For further questions, please contact:
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Adam Millard-Ball, University of California, Santa Cruz

References

Shlomo Angel, Alejandro M Blei, Daniel L Civco, and Jason Parent. *Atlas of urban expansion*. Lincoln Institute of Land Policy, Cambridge, MA, 2012. URL `http://atlasofurbanexpansion.org`.

Shlomo Angel, Alejandro M. Blei, Jason Parent, Patrick Lamson-Hall, Nicolás Galarza Sánchez, with Daniel L. Civco, Rachel Qian Lei, and Kevin Thom. *Atlas of Urban Expansion — 2016 Edition: Volume 1: Areas and Densities*. NYU Urban Expansion Program at New York University, UN-Habitat, and the Lincoln Institute of Land Policy, 2016. URL `http://www.lincolninst.edu/publications/other/atlas-urban-expansion-2016-edition`.

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Christopher Barrington-Leigh and Adam Millard-Ball. A global assessment of street network sprawl. *PLOS ONE*, 2019. doi: https://doi.org/10.1371/journal.pone.0223078.

Martino Pesaresi, Guo Huadong, Xavier Blaes, Daniele Ehrlich, Stefano Ferri, Lionel Gueguen, Matina Halkia, Mayeul Kauffmann, Thomas Kemper, Linlin Lu, et al. A global human settlement layer from optical HR/VHR RS data: concept and first results. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 6(5):2102–2131, 2013.

World Bank. World Bank Open Data, 2016. URL `https://blogs.worldbank.org/opendata/new-country-classifications-2016`. https://blogs.worldbank.org/opendata/new-country-classifications-2016.

F Supplemental reference book: results

The sections which follow contain more detailed tabular and graphical renditions of our findings. In addition, extensive online visualizations of our results are available at:
https://alum.mit.edu/www/cpbl/publications/2020-PNAS-sprawl
including an interactive map interface to our high-resolution results at:
https://sprawlmap.org.

F.1 Distribution of empirical street-network types

Figure S7 shows the trends over time in the distribution of empirical street-network types by World Bank-defined regions; it is similar to the plot in the main text, but includes additional regions. Figure S8 repeats the figure, but shows the distribution according to the fraction of grid cells (rather than the fraction of nodes) that fall into each cluster.

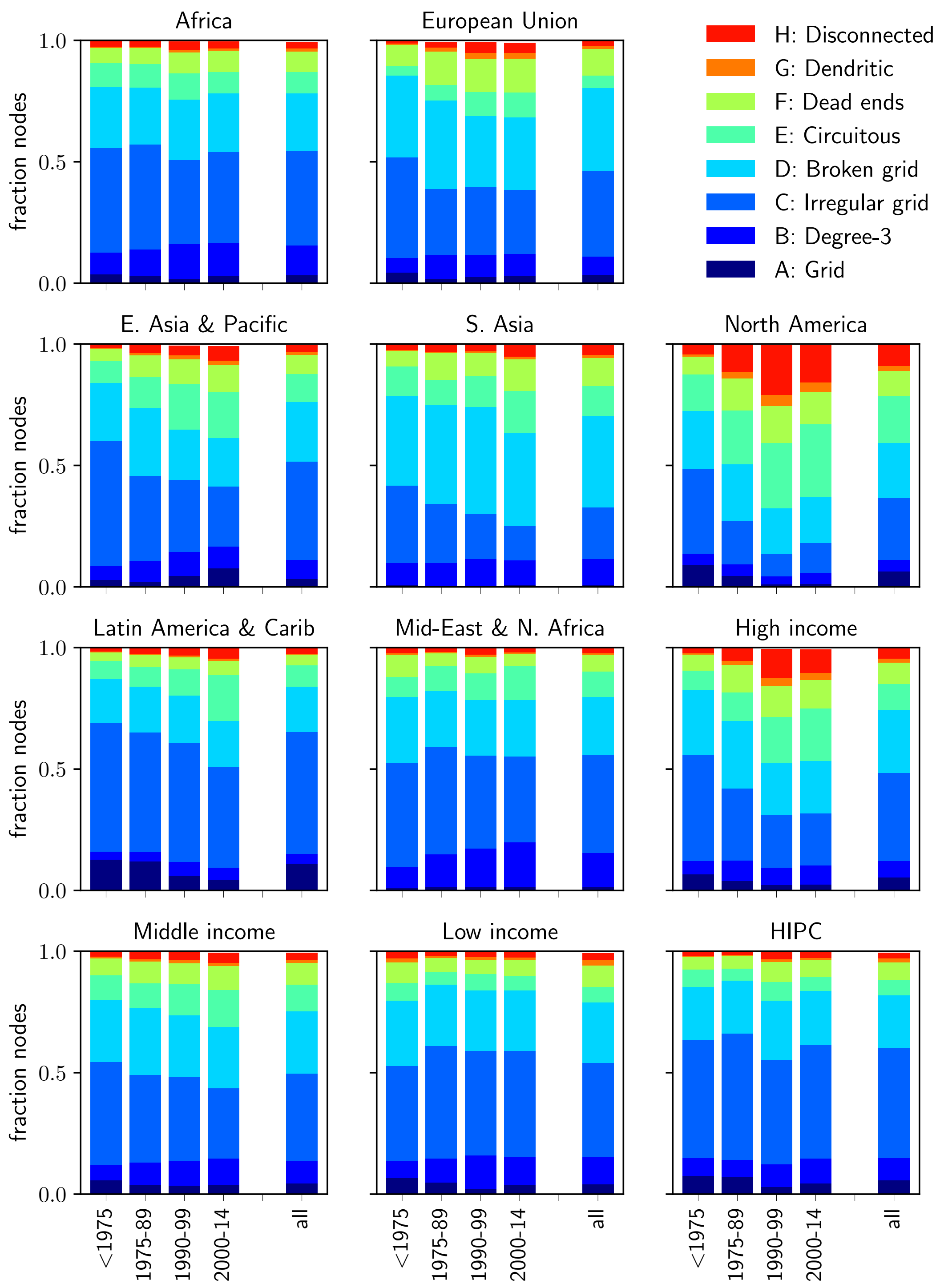


Figure S7: **Distribution of nodes by empirical type, by World Bank-defined region and year.** The bars represent the fraction of nodes in each type.

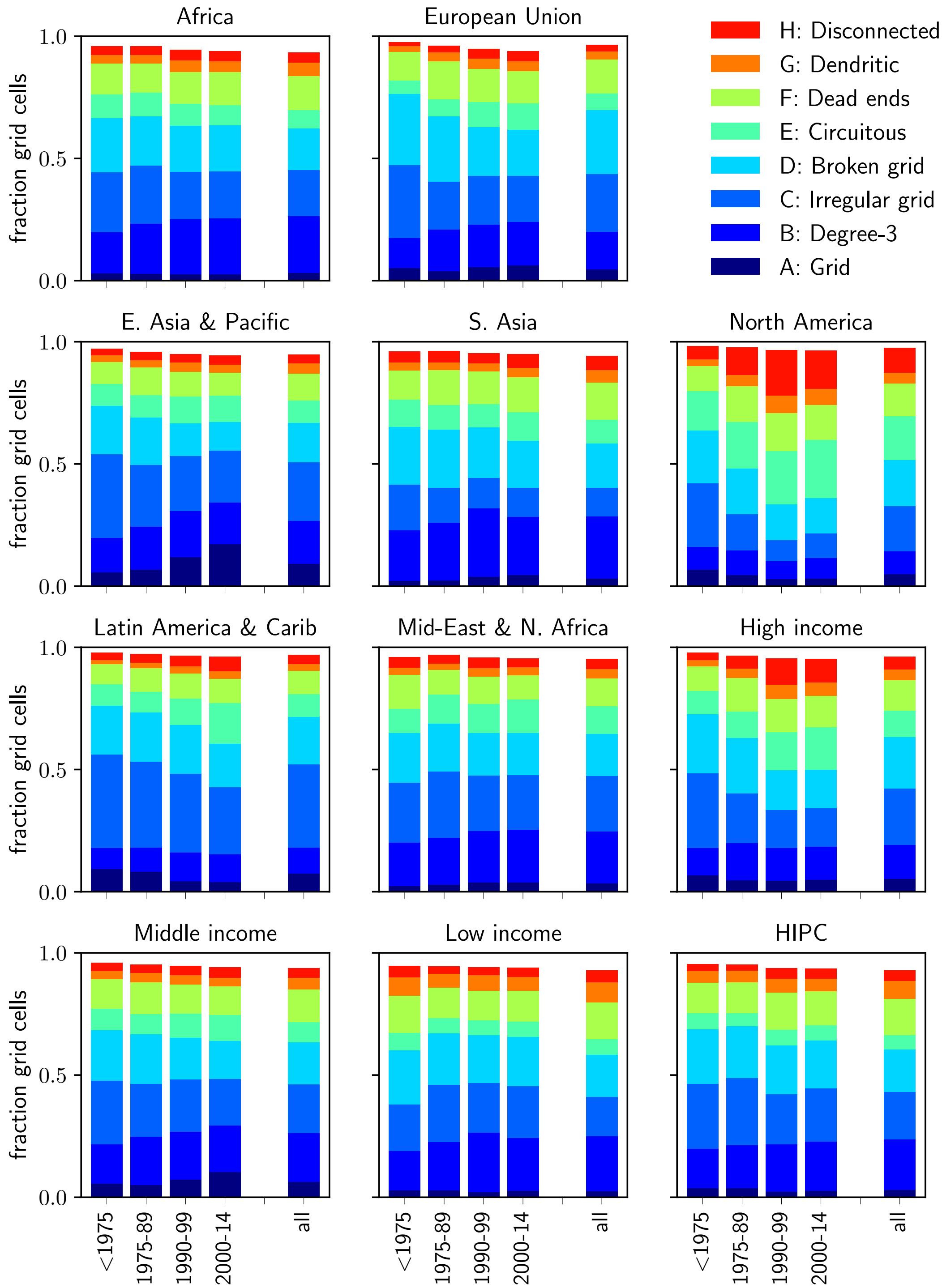


Figure S8: **Distribution of grid cells by empirical type, by World Bank-defined region and year.** The bars represent the fraction of grid cells in each type. (The two types that were dropped are not shown; hence, the bars do not add up to 100%.)

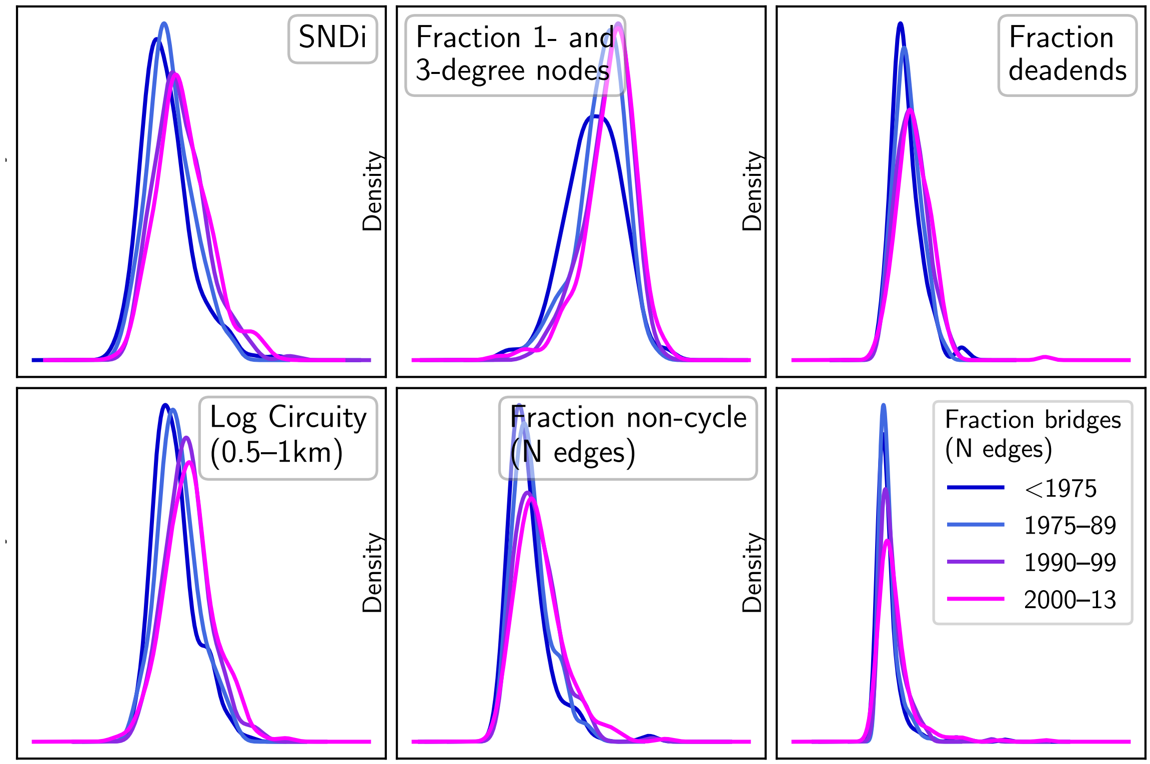


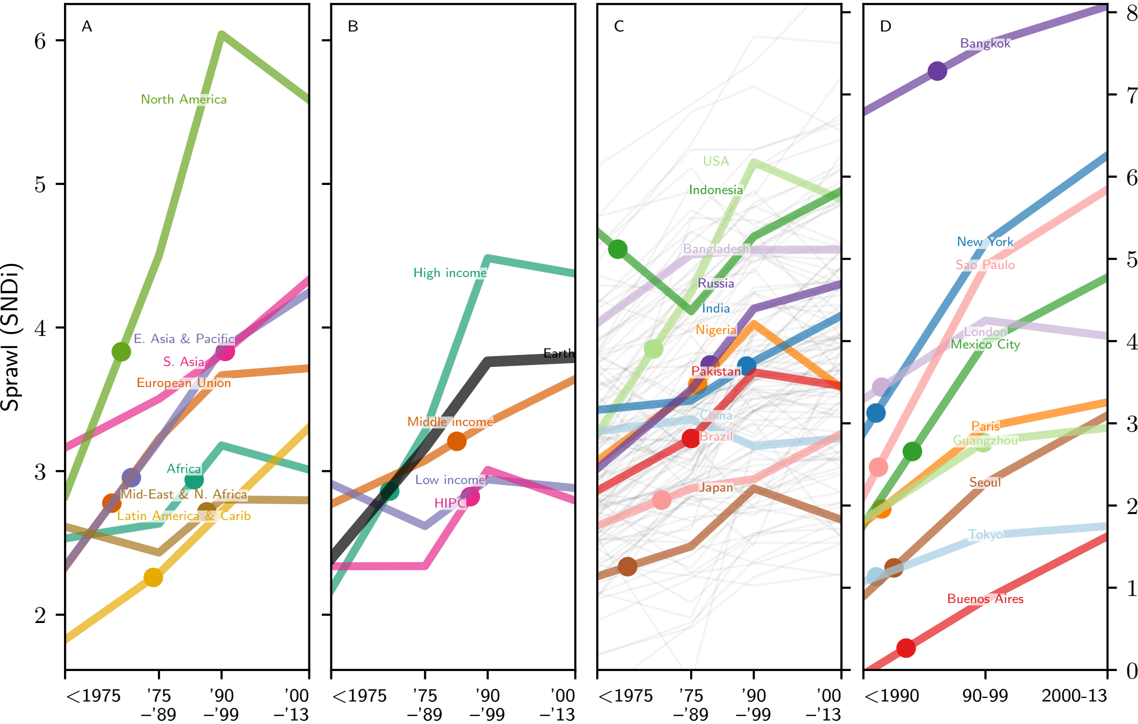
Figure S9: **Global shifts over time**. Curves show kernel density estimates of unweighted country-level means over urban nodes/edges, using built-up year classifications based on GHSL.

F.2 Trends and global distributions of key variables

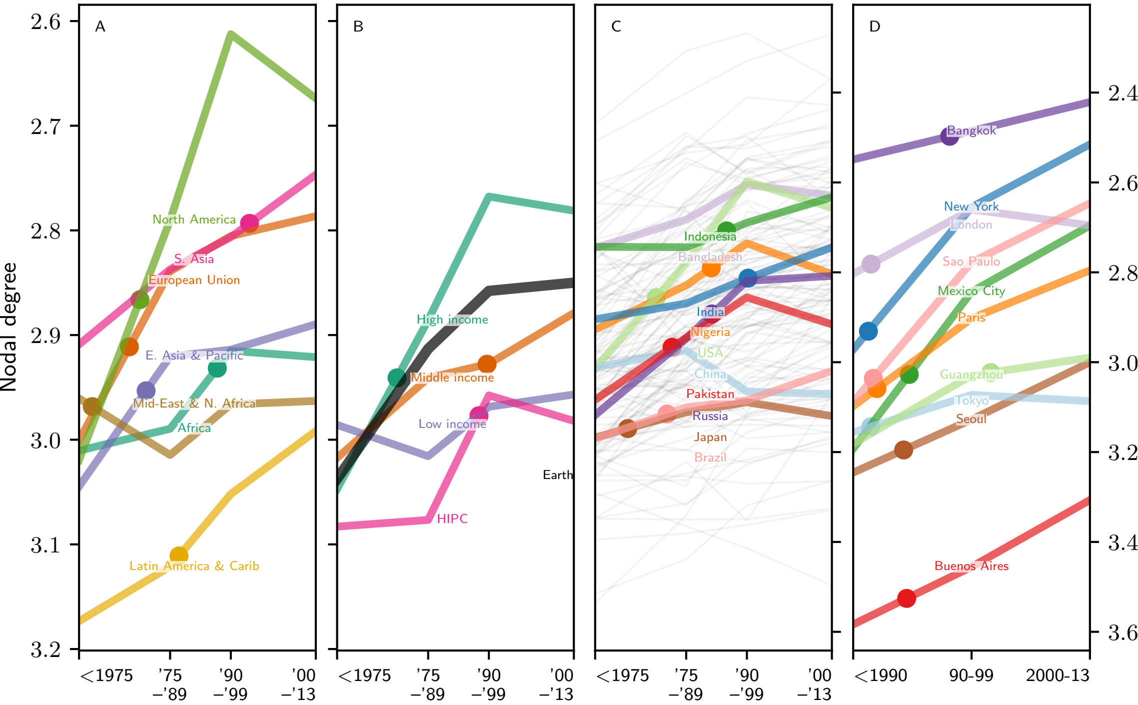
Our analysis emphasizes our aggregate (first principal component) measure of street-network sprawl, SNDi. Figure S9 shows how the global distributions of SNDi and five of its individual connectivity measures have evolved over time. In each case, there is a significant shift towards lower connectivity, but with a partial leveling off in the latest time period.

F.3 Summary trend plots for selected street-network sprawl measures

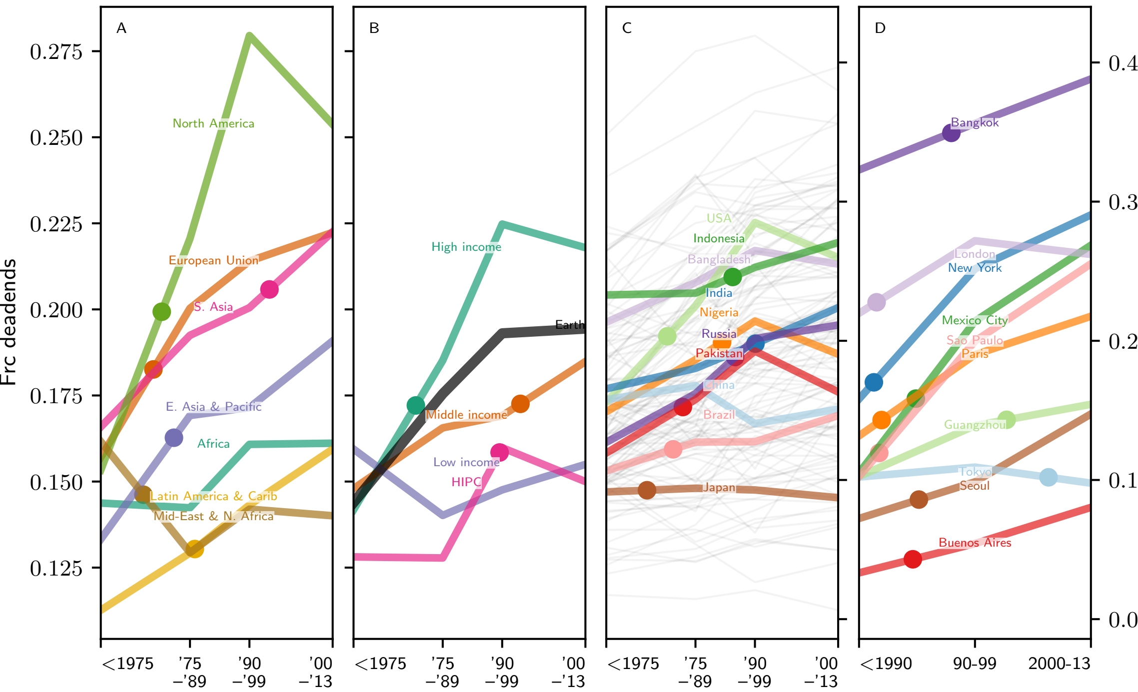
The following pages contain plots in the format of Figure 2 in the main text, but show trends of individual connectivity metrics making up our SNDi index. In each plot, the left two panels share a vertical axis, and the right two panels share a separate vertical axis.

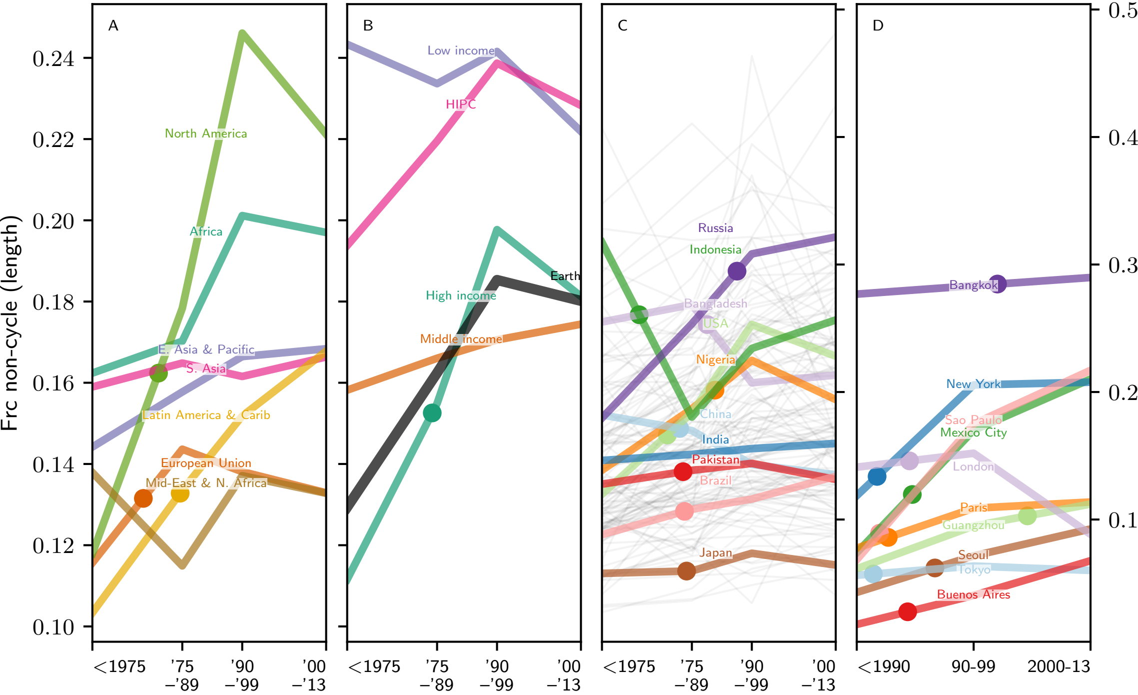


A
B
C
D
Sprawl (SNDi)
North America
E. Asia & Pacific
S. Asia
European Union
Africa
Mid-East & N. Africa
Latin America & Carib
High income
Earth
Middle income
Low income
HIPC
USA
Indonesia
Bangladesh
Russia
India
Nigeria
Pakistan
China
Brazil
Japan
Bangkok
New York
Sao Paulo
London
Mexico City
Paris
Guangzhou
Seoul
Tokyo
Buenos Aires
2
3
4
5
6
0
1
2
3
4
5
6
7
8
<1975
'75 –'89
'90 –'99
'00 –'13
<1990
90-99
2000-13

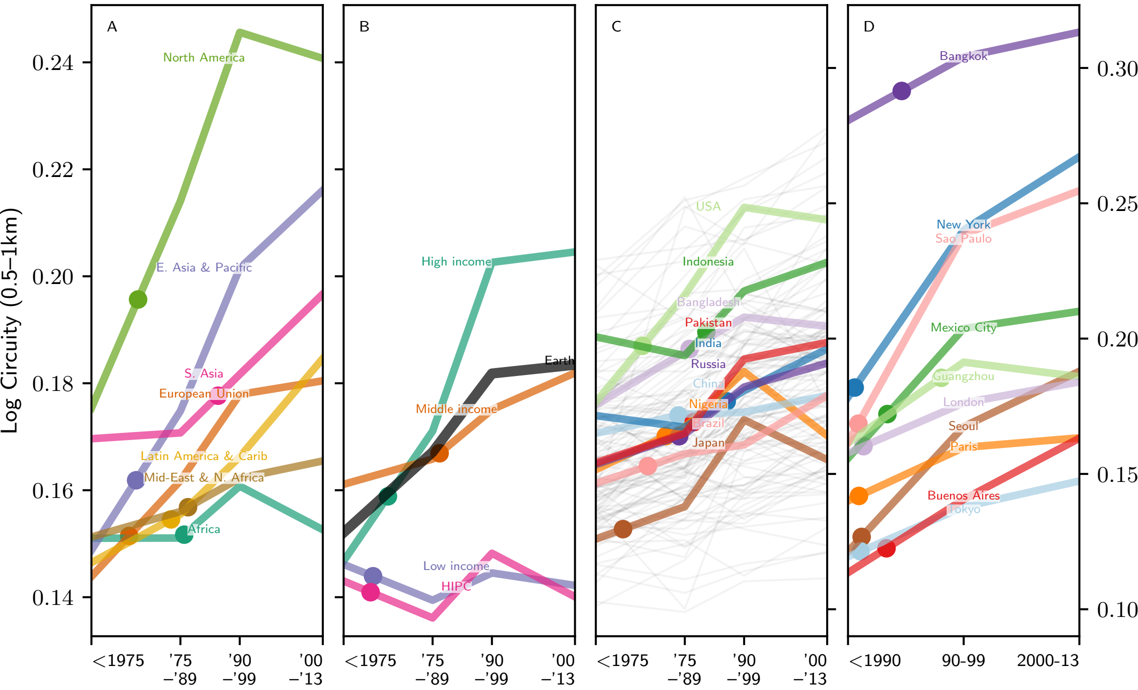


Nodal degree
A
B
C
D
2.6
2.7
2.8
2.9
3.0
3.1
3.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
North America
S. Asia
European Union
E. Asia & Pacific
Mid-East & N. Africa
Africa
Latin America & Carib
High income
Middle income
Low income
Earth
HIPC
Indonesia
Bangladesh
India
Nigeria
USA
China
Pakistan
Russia
Japan
Brazil
Bangkok
New York
London
Sao Paulo
Mexico City
Paris
Guangzhou
Tokyo
Seoul
Buenos Aires
<1975
'75 –'89
'90 –'99
'00 –'13
<1990
90-99
2000-13

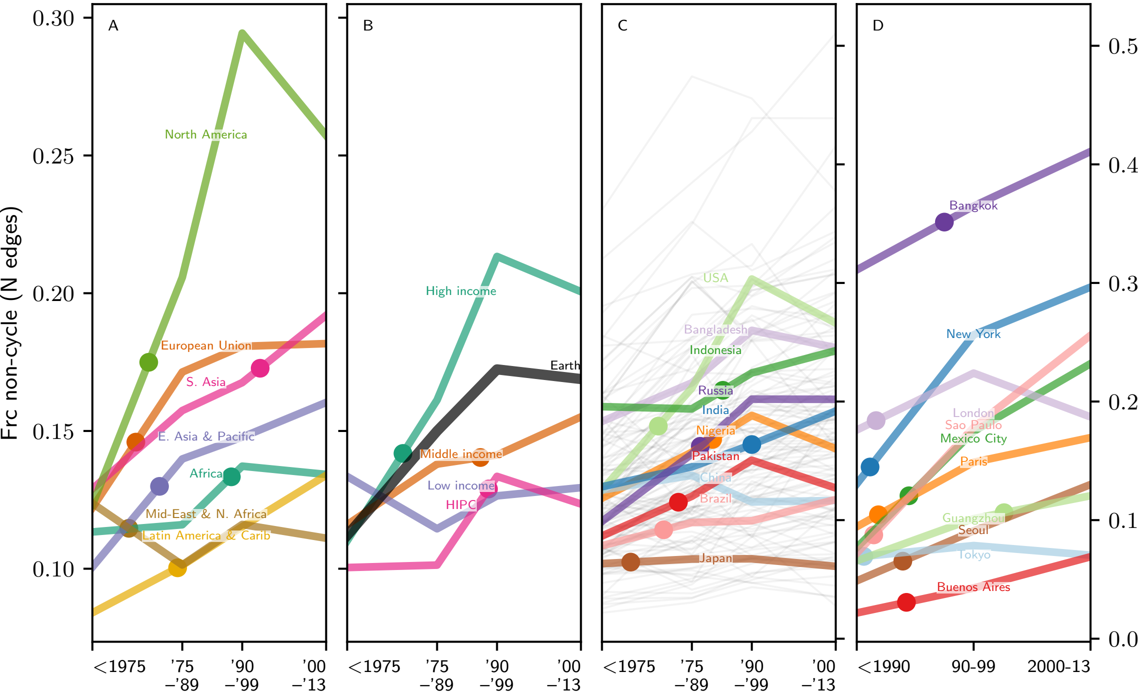

Frc deadends
A
B
C
D
North America
European Union
S. Asia
E. Asia & Pacific
Africa
Latin America & Carib
Mid-East & N. Africa
High income
Earth
Middle income
Low income
HIPC
USA
Indonesia
Bangladesh
India
Nigeria
Russia
Pakistan
China
Brazil
Japan
Bangkok
London
New York
Mexico City
Sao Paulo
Paris
Guangzhou
Tokyo
Seoul
Buenos Aires
0.275
0.250
0.225
0.200
0.175
0.150
0.125
0.4
0.3
0.2
0.1
0.0
<1975
'75 –'89
'90 –'99
'00 –'13
<1990
90-99
2000-13



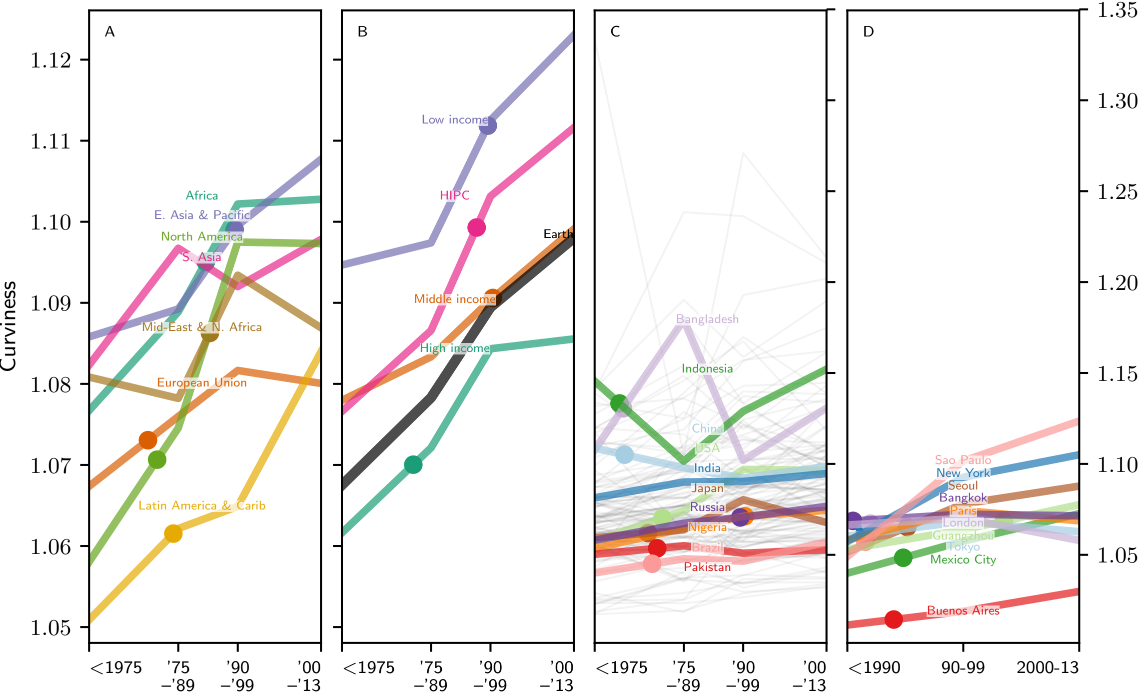
Frc non-cycle (length)
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
A
North America
Africa
E. Asia & Pacific
S. Asia
Latin America & Carib
European Union
Mid-East & N. Africa
B
Low income
HIPC
High income
Earth
Middle income
C
Russia
Indonesia
Bangladesh
USA
Nigeria
China
India
Pakistan
Brazil
Japan
D
Bangkok
New York
Sao Paulo
Mexico City
London
Paris
Guangzhou
Seoul
Tokyo
Buenos Aires
0.1
0.2
0.3
0.4
0.5
<1975
'75 –'89
'90 –'99
'00 –'13
<1990
90-99
2000-13



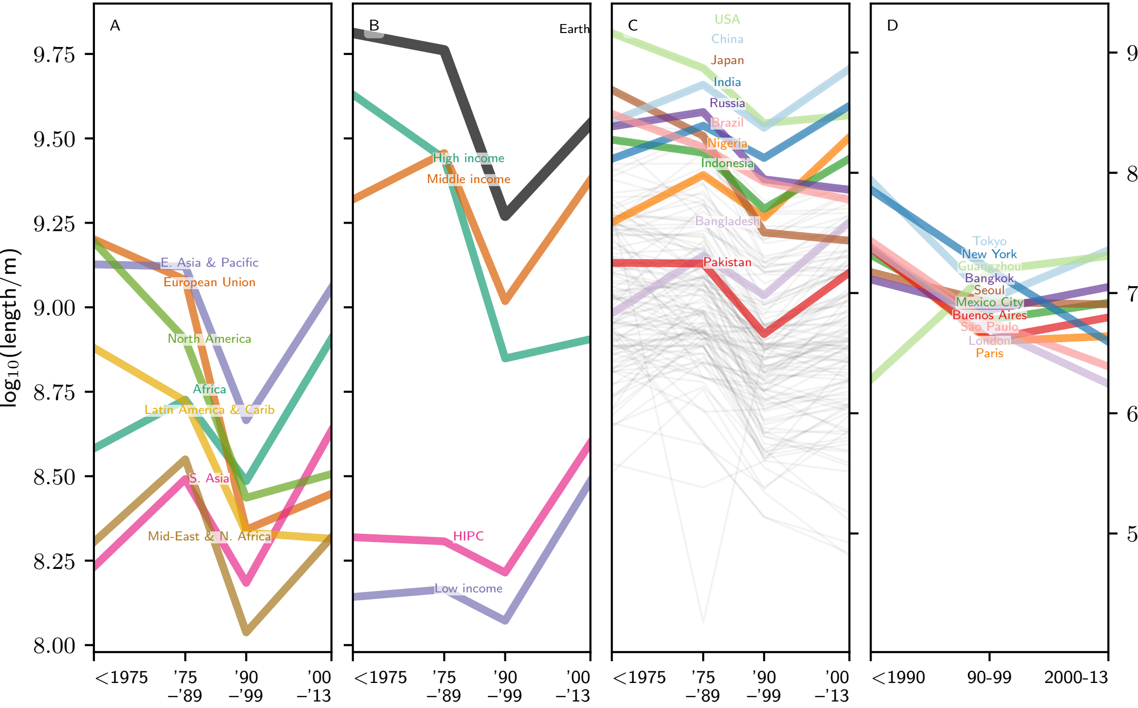
Log Circuity (0.5–1km)
A
North America
E. Asia & Pacific
S. Asia
European Union
Latin America & Carib
Mid-East & N. Africa
Africa
B
High income
Earth
Middle income
Low income
HIPC
C
USA
Indonesia
Bangladesh
Pakistan
India
Russia
China
Nigeria
Brazil
Japan
D
Bangkok
New York
Sao Paulo
Mexico City
Guangzhou
London
Seoul
Paris
Buenos Aires
Tokyo
0.24
0.22
0.20
0.18
0.16
0.14
0.30
0.25
0.20
0.15
0.10
<1975
'75 –'89
'90 –'99
'00 –'13
<1990
90-99
2000-13

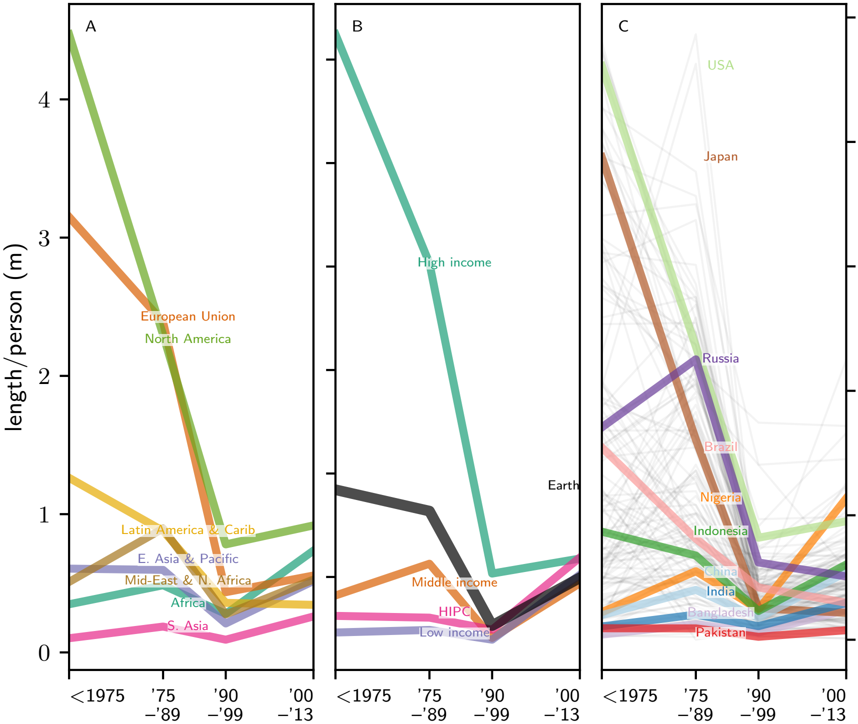


Frc non-cycle (N edges)
A
North America
European Union
S. Asia
E. Asia & Pacific
Africa
Mid-East & N. Africa
Latin America & Carib
B
High income
Earth
Middle income
Low income
HIPC
C
USA
Bangladesh
Indonesia
Russia
India
Nigeria
Pakistan
China
Brazil
Japan
D
Bangkok
New York
London
Sao Paulo
Mexico City
Paris
Guangzhou
Seoul
Tokyo
Buenos Aires
0.30
0.25
0.20
0.15
0.10
0.5
0.4
0.3
0.2
0.1
0.0
<1975
'75 –'89
'90 –'99
'00 –'13
<1990
90-99
2000-13



Curviness
A
B
C
D
Africa
E. Asia & Pacific
North America
S. Asia
Mid-East & N. Africa
European Union
Latin America & Carib
Low income
HIPC
Earth
Middle income
High income
Bangladesh
Indonesia
China
USA
India
Japan
Russia
Nigeria
Brazil
Pakistan
Sao Paulo
New York
Seoul
Bangkok
Paris
London
Guangzhou
Tokyo
Mexico City
Buenos Aires
1.05
1.06
1.07
1.08
1.09
1.10
1.11
1.12
1.05
1.10
1.15
1.20
1.25
1.30
1.35
<1975
'75 –'89
'90 –'99
'00 –'13
<1990
90-99
2000-13


A
B
C
D
Earth
log10(length/m)
9.75
9.50
9.25
9.00
8.75
8.50
8.25
8.00
9
8
7
6
5
E. Asia & Pacific
European Union
North America
Africa
Latin America & Carib
S. Asia
Mid-East & N. Africa
High income
Middle income
HIPC
Low income
USA
China
Japan
India
Russia
Brazil
Nigeria
Indonesia
Bangladesh
Pakistan
Tokyo
New York
Guangzhou
Bangkok
Seoul
Mexico City
Buenos Aires
Sao Paulo
London
Paris
<1975
'75 –'89
'90 –'99
'00 –'13
<1990
90-99
2000-13



A
B
C
length/person (m)
4
3
2
1
0
European Union
North America
Latin America & Carib
E. Asia & Pacific
Mid-East & N. Africa
Africa
S. Asia
High income
Earth
Middle income
HIPC
Low income
USA
Japan
Russia
Brazil
Nigeria
Indonesia
China
India
Bangladesh
Pakistan
<1975
'75 –'89
'90 –'99
'00 –'13

F.4 Road growth rates and connectivity

Our aggregations from individual road segments (edges) according to GHSL-determined epochs naturally produce estimates of the rate of road growth in each GADM region, grid cell, and Atlas of Urban Expansion city. Of course, these estimates are subject to the same uncertainties as our other calculations, namely the completeness of the OSM street database and the accuracy of GHSL and Atlas classifications.

Because global trends are driven by the size of additions to road stock, we explore the relationship between SNDi and the length of recent additions to the road stock, by city and by country (Figure S10 top row). There is no statistical relationship across cities, and only a weak one across countries. The countries with the largest road growth — China, India, United States, Nigeria, Indonesia, and South Africa — span the range of relatively low to relatively high SNDi. China's construction of 655,000 km of urban roads during this period is equal to nearly half the entire urban stock in the USA in 1975. Among cities, Bangkok and Tokyo stand out again; Bangkok is among the fastest growing cities, as well as an outlier in the low connectivity of its new street development. Meanwhile, Tokyo and Guangzhou are examples of equally fast or faster growth but with high connectivity. Houston appears to be a (fast-growing) low-connectivity city in the global picture.

In addition to analyzing SNDi against the *magnitude* of growth in roads, we compare it to the *rate* of growth. We define the growth rate of road networks as $R/(S-R)$, where R is the addition to length in the most recent period (2000-2013) and S is the length of the current stock. Figure S10 (bottom row) shows the relationship between recent SNDi and the road growth rate. Faster-growing cities tend to be building more-connected roads, perhaps largely due to the existence of rapidly-growing, initially-small cities in China. While a relationship holds also across countries, it does not hold statistically within any of our world regions (not shown). In terms of growth rate, the largest countries are in Africa. Similarly, as measured by road length per capita (not shown), African countries make up ten of the top 14 fastest builders. Notably, China is a significant investor in growing African infrastructure.

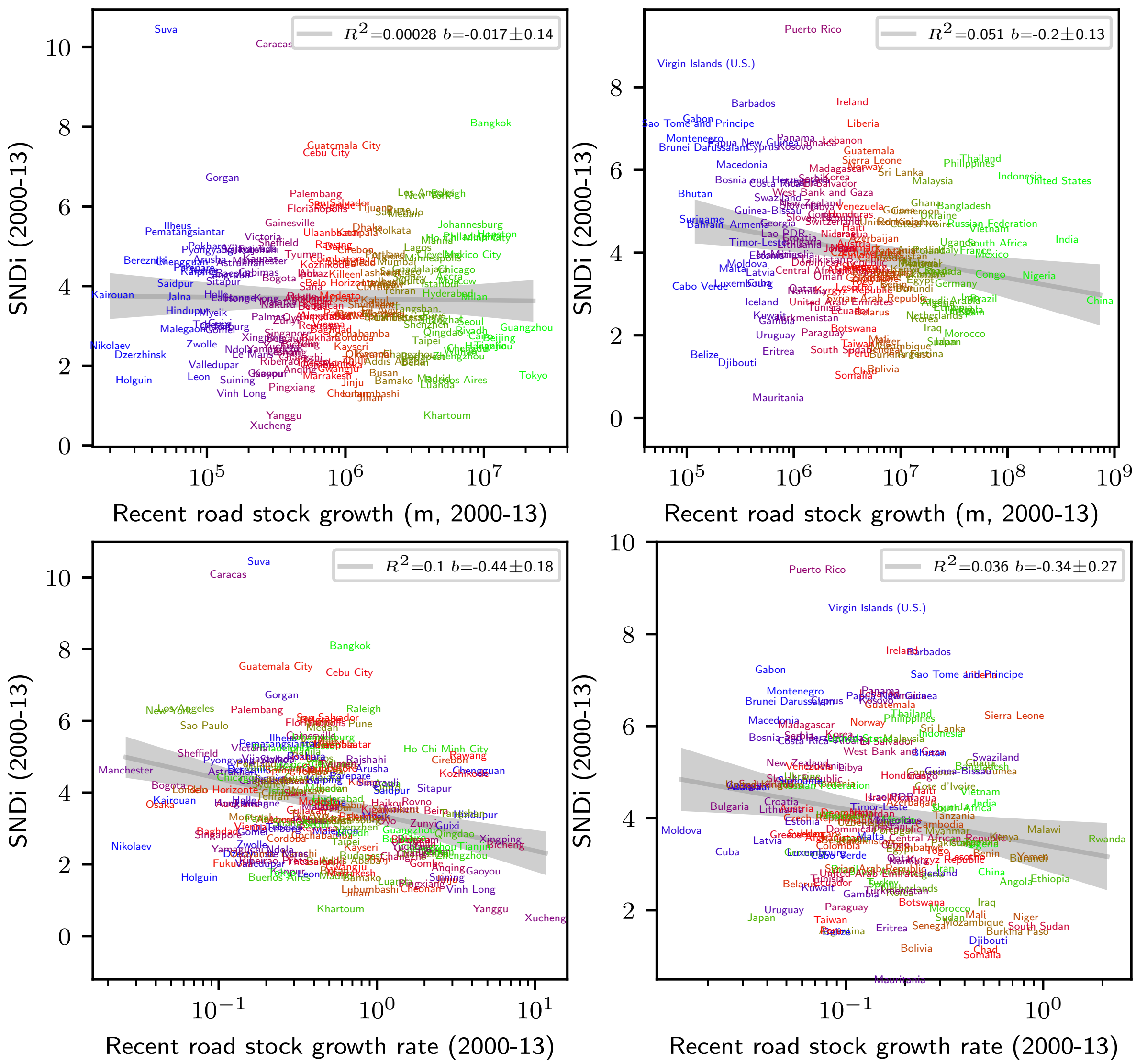


Figure S10: **Rate of road growth and SNDi**. Relationships between recently-constructed (2000–2013) street-network sprawl and (top row) recent additions to road stock or (bottom row) recent growth rate of road stock. Cities are shown on the left, and countries on the right. Coefficients (b) from OLS fits are shown with 95% confidence range. Colors in the lower panels are defined by the abscissa of the upper ones.

F.5 Countries ranked by urban street-network sprawl (SNDi) of recent road development

Table S1: **Countries listed in order of recent urban street-network sprawl (SNDi)**. Countries with large (>20M) population are listed in bold.

	Sprawl (SNDi)					Nodal degree					N(nodes)				
	<1975	75–89	90–99	2000–13	Stock	<1975	75–89	90–99	2000–13	Stock	<1975	75–89	90–99	2000–13	Stock
Puerto Rico	4.9	7.7	8.9	9.4	6.5	2.7	2.4	2.3	2.3	2.5	54k	47k	12k	8.2k	120k
Virgin Islands (U.S.)	4.9	7.9	8.1	8.6	7.4	2.8	2.4	2.4	2.4	2.5	1.1k	2.5k	880	690	5.3k
Trinidad and Tobago	6.1		7.4	8.5	6.2	2.5		2.3	2.3	2.5	28k		750	470	30k
Ireland	5.0	6.4	7.7	7.6	5.9	2.7	2.5	2.4	2.4	2.6	57k	22k	17k	19k	120k
Barbados	6.1		7.2	7.6	6.4	2.5		2.4	2.3	2.4	9.3k		960	2k	13k
Gabon	5.5	5.8	5.8	7.2	5.9	2.6	2.5	2.5	2.4	2.5	3.3k	8.1k	2.3k	500	15k
Liberia	6.2	7.7	7.6	7.1	6.9	2.6	2.4	2.4	2.4	2.5	13k	2.4k	2.4k	3k	22k
Panama	3.2	4.7	6.1	6.8	4.6	3.0	2.8	2.6	2.5	2.8	15k	9.3k	7.1k	4.8k	37k
Montenegro	3.4	5.0	5.9	6.7	4.5	2.9	2.6	2.5	2.3	2.7	3.7k	3.7k	310	340	8.6k
Lebanon	2.1	5.5	6.3	6.7	3.9	3.0	2.6	2.5	2.5	2.7	17k	18k	4k	3.9k	45k
Jamaica	5.2	6.3	6.3	6.6	5.6	2.6	2.5	2.5	2.5	2.6	19k	5.5k	3.8k	3.2k	33k
Papua New Guinea	6.0	5.5	7.1	6.6	6.5	2.6	2.6	2.4	2.7	2.6	3.7k	870	270	250	6.2k
Kosovo	5.5	6.8	7.1	6.6	6.4	2.5	2.3	2.3	2.4	2.3	14k	18k	2.3k	3.5k	41k
Cyprus	2.8	4.0	5.6	6.5	4.2	2.8	2.7	2.6	2.5	2.7	6.7k	26k	4.8k	2.9k	41k
Brunei Darussalam	6.1	7.4	7.0	6.5	6.7	2.5	2.3	2.4	2.5	2.4	6.2k	5.3k	1.5k	610	14k
Guatemala	3.2	4.7	6.1	6.5	4.6	3.0	2.9	2.7	2.7	2.9	32k	41k	12k	11k	110k
Bahamas, The	4.8	4.5	6.2	6.3	4.8	2.7	2.8	2.6	2.6	2.7	4.8k	3.1k	630	320	9.2k
Thailand	4.0	4.7	4.8	6.3	4.9	2.8	2.8	2.7	2.6	2.7	140k	470k	74k	120k	920k
Sierra Leone	4.5	6.6	6.0	6.2	5.7	2.7	2.5	2.5	2.5	2.6	8.7k	3.2k	2.6k	9k	25k
Philippines	4.5	5.3	5.6	6.1	5.4	3.0	2.8	2.8	2.8	2.8	130k	200k	51k	59k	500k
Macedonia, FYR	4.0	4.7	5.3	6.1	4.6	2.7	2.6	2.5	2.4	2.6	9k	24k	1.3k	800	36k
Norway	4.0	4.8	5.7	6.1	4.6	2.9	2.7	2.6	2.6	2.8	62k	57k	10k	19k	170k
Madagascar	4.1	4.6	7.3	6.0	5.3	3.1	2.8	2.6	2.6	2.7	5.8k	8.7k	1.6k	2.1k	39k
Sri Lanka	3.8	5.9	5.4	5.9	5.5	2.7	2.5	2.6	2.5	2.5	22k	78k	8k	26k	150k
Indonesia	5.3	4.4	5.3	5.8	5.1	2.7	2.7	2.7	2.6	2.7	660k	470k	140k	220k	1.6M
Korea, Dem. People's Rep.	5.1	6.1	5.1	5.8	5.4	2.6	2.5	2.6	2.5	2.6	39k	7.2k	2.2k	2.8k	58k
Serbia	3.0	4.3	5.3	5.8	3.8	2.9	2.7	2.5	2.5	2.8	56k	32k	4.1k	4.7k	100k
Bosnia and Herzegovina	3.9	5.3	4.9	5.7	4.8	2.8	2.6	2.6	2.5	2.6	19k	17k	1.7k	2k	42k

	Sprawl (SNDi)					Nodal degree					N(nodes)				
	<1975	75–89	90–99	2000–13	Stock	<1975	75–89	90–99	2000–13	Stock	<1975	75–89	90–99	2000–13	Stock
United States	2.9	4.6	6.2	5.7	3.9	3.0	2.8	2.6	2.7	2.9	5.5M	2.7M	980k	1.1M	11M
Malaysia	4.5	5.6	5.2	5.7	4.9	2.9	2.7	2.8	2.8	2.8	270k	49k	47k	45k	420k
Albania	4.7	4.6	5.4	5.7	4.9	2.6	2.7	2.6	2.5	2.6	8.3k	21k	5.6k	2.6k	41k
Costa Rica	4.4	5.1	5.1	5.7	4.7	2.8	2.7	2.6	2.6	2.7	35k	17k	3.9k	2.6k	61k
El Salvador	3.4	4.3	5.1	5.7	4.3	2.9	2.8	2.7	2.6	2.8	16k	30k	10k	6.6k	66k
West Bank and Gaza	2.9	4.4	5.2	5.4	4.5	2.9	2.6	2.6	2.5	2.6	8.3k	29k	9.4k	6.2k	55k
New Zealand	3.7		5.6	5.2	4.0	2.8		2.6	2.7	2.8	75k		4.9k	5k	96k
Ghana	3.7	4.4	5.0	5.2	4.6	2.8	2.7	2.6	2.6	2.7	39k	25k	26k	36k	130k
Slovenia	4.2	5.5	5.5	5.1	4.5	2.7	2.5	2.6	2.6	2.6	40k	16k	1.1k	2.5k	61k
Bangladesh	4.2	5.1	5.1	5.1	5.3	2.7	2.7	2.6	2.6	2.6	16k	36k	7.7k	26k	160k
Venezuela, RB	3.3		4.1	5.1	3.4	3.0		2.9	2.8	3.0	240k		23k	15k	290k
Libya	1.7	2.4	4.1	5.1	2.3	3.1	3.0	2.8	2.7	3.0	46k	25k	5.2k	8.5k	86k
Guinea	2.5	3.6	4.0	5.0	4.0	3.0	2.9	2.8	2.7	2.8	13k	12k	8k	14k	52k
Cameroon	3.7	3.7	5.0	5.0	4.5	2.9	2.8	2.6	2.6	2.7	36k	34k	34k	28k	150k
Honduras	2.3	3.3	3.8	4.9	3.4	3.2	3.1	3.0	2.8	3.1	23k	21k	18k	9.4k	75k
Congo, Rep.	2.0	2.7	3.8	4.9	2.7	3.2	3.0	2.9	2.7	3.1	33k	6k	5.5k	8.1k	53k
Ukraine	2.6	3.3	4.3	4.9	3.4	3.0	2.9	2.7	2.6	2.8	230k	370k	37k	28k	760k
Slovak Republic	2.8	4.2	5.1	4.8	3.5	2.9	2.6	2.5	2.6	2.8	58k	39k	3.3k	5k	110k
Suriname	3.1		4.9	4.8	3.2	2.9		2.7	2.7	2.9	8.4k		270	570	9.4k
Romania	2.7	3.7	4.6	4.7	3.4	2.9	2.7	2.6	2.6	2.7	150k	160k	17k	24k	370k
Switzerland	1.8	3.8	4.7	4.7	2.6	3.1	2.8	2.7	2.6	3.0	120k	68k	6.2k	7k	210k
United Kingdom	3.8	5.2	5.8	4.7	4.1	2.7	2.5	2.5	2.6	2.7	1.3M	240k	42k	44k	1.6M
Georgia	3.8	4.1	5.1	4.7	4.1	2.7	2.7	2.5	2.6	2.7	54k	27k	2.8k	2.2k	95k
Russian Federation	2.4	3.4	4.4	4.7	3.7	3.1	2.9	2.8	2.8	2.9	620k	600k	140k	100k	1.9M
Cote d'Ivoire	2.8	2.8	4.2	4.7	3.3	3.0	2.9	2.7	2.6	2.9	51k	9.6k	7k	8.4k	79k
Bahrain	2.1	2.7	3.5	4.7	2.5	3.1	3.0	2.9	2.9	3.0	17k	11k	1.6k	690	30k
Armenia	3.4	3.8	3.9	4.7	3.8	2.9	2.8	2.8	2.7	2.8	21k	17k	2.6k	1.4k	46k
Haiti	3.6	4.6	5.1	4.6	4.6	3.0	2.7	2.7	2.7	2.7	10k	12k	3.4k	7.1k	40k
Vietnam	3.9	4.2	4.4	4.6	4.4	2.8	2.7	2.8	2.8	2.8	67k	99k	28k	68k	290k
Lao PDR	3.3	3.7	4.5	4.4	4.0	2.8	2.7	2.7	2.7	2.7	4.7k	4.8k	2.4k	2.5k	18k
Israel	2.0	3.2	4.4	4.4	3.3	3.1	2.9	2.8	2.8	2.9	17k	53k	16k	12k	99k
Nicaragua	1.6	2.5	3.7	4.4	2.8	3.3	3.1	2.9	2.8	3.0	17k	14k	7.6k	6.2k	49k
Croatia	3.1	4.4	5.1	4.3	3.7	2.9	2.6	2.6	2.7	2.7	46k	32k	2.7k	2.7k	87k
Azerbaijan	4.8	4.5	4.4	4.3	4.6	2.6	2.7	2.7	2.7	2.6	39k	53k	7k	20k	130k

	Sprawl (SNDi)					Nodal degree					N(nodes)				
	<1975	75–89	90–99	2000–13	Stock	<1975	75–89	90–99	2000–13	Stock	<1975	75–89	90–99	2000–13	Stock
India	3.2	3.3	3.8	4.3	3.7	2.9	2.9	2.8	2.7	2.8	510k	740k	320k	550k	2.4M
Bulgaria	1.6	1.7	4.1	4.2	1.8	3.1	3.0	2.7	2.7	3.0	98k	110k	4.2k	4k	230k
Uganda	4.2	3.4	3.9	4.2	4.7	2.7	2.8	2.8	2.7	2.6	11k	4.4k	11k	15k	120k
South Africa	3.0	3.8	3.7	4.2	3.6	3.0	2.9	2.9	2.8	2.9	170k	240k	110k	110k	660k
Austria	2.5	3.4	4.6	4.2	2.9	3.0	2.8	2.7	2.7	2.9	150k	76k	13k	13k	260k
Lithuania	1.6	2.7	3.7	4.2	2.9	3.2	3.0	2.8	2.8	2.9	16k	15k	3.6k	1.9k	57k
Nepal	3.8	3.2	2.9	4.1	4.0	2.8	2.8	2.9	2.7	2.7	19k	9.6k	3.6k	5.3k	63k
Denmark	2.5	3.1	3.6	4.1	2.9	2.9	2.8	2.8	2.7	2.9	130k	77k	9.7k	19k	240k
Jordan	2.8	2.6	3.5	4.1	3.0	3.0	3.0	2.8	2.8	2.9	5.4k	56k	13k	11k	93k
Italy	2.2	3.5	4.0	4.1	2.8	3.0	2.8	2.8	2.7	2.9	790k	580k	60k	74k	1.5M
Australia	2.7	4.5	5.3	4.1	3.5	3.0	2.7	2.6	2.8	2.9	380k	220k	42k	64k	710k
Poland	1.9	3.0	3.9	4.0	2.6	3.1	2.9	2.7	2.7	2.9	230k	210k	25k	39k	530k
Tanzania	3.0	2.4	3.8	4.0	3.5	2.9	2.9	2.8	2.8	2.8	25k	13k	20k	31k	110k
France	2.3	3.6	3.9	4.0	2.9	3.0	2.8	2.7	2.7	2.9	1.1M	780k	140k	150k	2.2M
Czech Republic	2.0	3.2	3.7	4.0	2.6	3.0	2.8	2.7	2.7	2.9	150k	89k	7.4k	15k	270k
Mexico	1.7	2.4	3.1	3.9	2.6	3.2	3.1	3.0	3.0	3.1	430k	760k	240k	280k	1.9M
Mongolia	3.4	4.2	4.6	3.9	3.7	2.8	2.7	2.8	2.8	2.8	1.5k	6.5k	830	3.4k	27k
Finland	2.0	2.8	3.5	3.9	3.1	3.2	3.0	2.9	2.9	2.9	54k	40k	11k	15k	160k
Mauritius	2.9			3.9	3.0	2.9			2.8	2.8	17k			3k	21k
Estonia	1.5	2.4	4.1	3.9	2.6	3.2	3.0	2.8	2.9	3.0	12k	9.6k	1.2k	1.5k	33k
Hong Kong SAR, China	1.1	2.1	1.5	3.9	1.4	3.3	3.2	3.4	3.1	3.3	7.5k	3k	530	130	11k
Uzbekistan	3.2	3.1	3.9	3.9	3.5	2.9	2.9	2.8	2.7	2.8	78k	65k	13k	18k	210k
Cambodia	2.3	2.8	3.2	3.9	3.3	3.1	2.9	2.9	2.9	2.9	2.5k	11k	4.4k	12k	41k
Tajikistan	3.8	3.3	3.5	3.8	4.0	2.8	2.9	2.8	2.8	2.8	9.9k	8.3k	1.5k	4.1k	33k
Dominican Republic	1.7	3.1	2.8	3.7	2.7	3.2	3.0	3.0	2.9	3.0	35k	43k	20k	12k	110k
Malawi	3.8	3.6	3.9	3.7	3.7	2.8	2.8	2.7	2.7	2.8	11k	6.1k	6.6k	23k	58k
Portugal	2.8	3.2	3.8	3.7	3.1	3.0	2.9	2.8	2.8	2.9	170k	140k	45k	33k	390k
Moldova	2.3	2.7	3.1	3.7	2.6	2.9	2.9	2.8	2.7	2.9	29k	54k	2.6k	1.4k	88k
Myanmar	2.8	2.8	2.0	3.7	3.0	3.0	3.0	3.1	2.9	2.9	30k	49k	29k	35k	180k
Hungary	1.6	2.8	3.5	3.6	2.3	3.1	2.9	2.8	2.7	2.9	120k	86k	8.8k	11k	230k
Sweden	2.0	3.1	3.6	3.6	2.6	3.1	2.9	2.9	2.9	3.0	170k	61k	11k	15k	300k
Greece	0.9	2.4	3.2	3.6	1.5	3.2	2.9	2.8	2.8	3.1	200k	140k	13k	11k	380k
Malta	1.0	1.9	3.1	3.6	1.7	3.3	3.1	2.9	2.8	3.1	4.5k	7.2k	290	580	13k
Kenya	4.5	4.1	4.9	3.6	4.1	2.8	2.8	2.7	2.8	2.7	3.2k	12k	7.5k	20k	58k

	Sprawl (SNDi)					Nodal degree					N(nodes)				
	<1975	75–89	90–99	2000–13	Stock	<1975	75–89	90–99	2000–13	Stock	<1975	75–89	90–99	2000–13	Stock
Afghanistan	5.6	3.8	5.3	3.6	4.8	2.6	2.8	2.6	3.0	2.7	6k	13k	2.1k	8.3k	97k
Central African Republic	2.9	3.7	3.9	3.6	3.6	3.0	3.0	3.0	3.0	3.0	5.3k	1.3k	2.3k	1.5k	12k
Canada	2.2	3.2	3.7	3.5	2.7	3.1	3.0	2.9	3.0	3.0	370k	190k	49k	66k	720k
Rwanda	2.5	3.4	3.5	3.5	3.7	3.0	2.9	2.9	2.9	2.8	470	3.6k	1.2k	7.3k	15k
Belgium	1.6	2.8	3.4	3.5	2.2	3.1	2.9	2.8	2.7	3.0	160k	93k	15k	18k	290k
Latvia	1.5	2.3	3.7	3.5	2.6	3.2	3.0	2.8	2.9	2.9	14k	13k	2.2k	1.5k	46k
Kazakhstan	2.9	2.5	3.2	3.5	3.0	3.0	3.1	3.0	3.0	3.0	33k	64k	9.4k	15k	150k
Zambia	2.4	2.9	3.3	3.5	3.3	3.0	3.0	2.9	2.9	2.9	27k	9.7k	4k	15k	73k
Congo, Dem. Rep.	3.0	3.2	3.3	3.5	3.6	3.1	3.1	3.0	2.9	2.9	86k	55k	36k	63k	290k
Pakistan	2.2	2.8	3.6	3.5	2.8	3.1	2.9	2.9	2.9	3.0	78k	78k	23k	53k	250k
Nigeria	2.5	3.4	4.2	3.4	3.5	2.9	2.8	2.7	2.8	2.8	160k	260k	110k	430k	1.3M
Chile	2.0	2.6	3.2	3.4	2.6	3.1	3.0	2.9	2.9	3.0	130k	80k	46k	51k	320k
Oman	3.7	2.8	3.5	3.4	3.4	2.7	3.0	2.8	2.9	2.8	7.7k	11k	8.4k	7.6k	53k
Colombia	1.6	-0.1	2.8	3.4	1.8	3.2	3.3	3.0	2.9	3.2	290k	120	22k	23k	350k
Zimbabwe	2.5	3.0	3.4	3.4	3.1	3.0	2.9	2.9	2.9	2.9	8k	25k	14k	9.6k	66k
Egypt, Arab Rep.	3.5	3.1	3.4	3.3	3.4	2.8	2.9	2.8	2.9	2.9	240k	110k	31k	54k	460k
Togo	2.1	2.0	2.3	3.3	2.6	3.0	3.0	3.0	2.8	2.9	14k	12k	8.1k	11k	53k
Cuba	0.9	2.2	2.7	3.3	1.4	3.3	3.0	2.9	2.8	3.1	60k	37k	3k	2.3k	100k
Luxembourg	2.0	2.9	3.2	3.2	2.4	3.1	2.9	2.9	2.8	3.0	8.3k	5.3k	1.3k	910	16k
Germany	1.9	3.0	3.2	3.2	2.3	3.1	2.9	2.8	2.8	3.0	1.4M	640k	100k	110k	2.3M
Benin	1.3	2.1	2.3	3.2	2.5	3.1	3.0	3.0	2.8	2.9	12k	18k	15k	17k	68k
Cabo Verde	2.6			3.2	2.8	3.1			3.0	3.1	3.3k			480	5.7k
Lesotho	3.5	2.8	2.7	3.1	3.4	2.8	2.9	2.9	2.9	2.8	800	8.4k	9.1k	12k	43k
Yemen, Rep.	3.3	2.2	3.4	3.1	3.3	3.0	3.1	3.0	3.0	3.0	4k	13k	3k	19k	48k
Qatar	2.4	3.0	3.2	3.1	2.9	3.1	3.0	3.0	3.0	3.0	7.5k	17k	1.6k	4.2k	33k
Burundi	2.4	3.2	3.7	3.1	3.3	3.2	2.9	2.9	2.9	2.9	1.5k	2.7k	2.7k	6.9k	20k
Kyrgyz Republic	2.9	3.2	3.0	3.1	3.2	2.9	2.9	2.9	2.9	2.9	11k	17k	5.3k	13k	52k
Namibia	2.0	2.2	3.4	3.1	2.8	3.1	3.1	2.9	3.0	3.0	2.3k	5k	4k	3.9k	18k
Iran, Islamic Rep.	3.5	2.7	3.0	2.9	3.0	2.7	2.9	2.9	2.9	2.9	210k	370k	79k	200k	950k
Syrian Arab Republic	1.3	1.8	2.3	2.9	1.7	3.1	3.1	2.9	2.9	3.0	81k	70k	12k	17k	190k
Brazil	1.8	2.2	2.3	2.9	2.1	3.2	3.1	3.1	3.0	3.1	1.6M	820k	430k	280k	3.4M

	Sprawl (SNDi)					Nodal degree					N(nodes)				
	<1975	75–89	90–99	2000–13	Stock	<1975	75–89	90–99	2000–13	Stock	<1975	75–89	90–99	2000–13	Stock
Saudi Arabia	2.0	2.3	2.8	2.8	2.9	3.2	3.1	3.1	3.1	3.1	58k	160k	40k	66k	420k
China	2.9	3.0	2.7	2.8	3.1	3.0	3.0	3.1	3.1	3.0	340k	520k	220k	460k	1.9M
Iceland	1.9		3.3	2.8	2.5	3.1		2.9	3.0	3.0	5.6k		960	2.4k	12k
United Arab Emirates	1.7	1.2	2.2	2.8	1.9	3.2	3.2	3.1	3.1	3.1	40k	11k	5.4k	9.3k	90k
Algeria	2.5	2.1	2.1	2.8	2.3	3.0	3.1	3.1	3.0	3.0	35k	240k	63k	57k	410k
Tunisia	1.7	2.0	1.9	2.7	1.9	3.1	3.0	3.1	3.0	3.0	37k	83k	21k	9.5k	150k
Ethiopia	2.8	2.5	2.4	2.7	2.7	3.0	3.0	3.1	3.1	3.0	6.7k	23k	21k	99k	190k
Angola	2.8	3.4	3.4	2.6	2.9	3.0	2.9	3.0	3.1	3.0	27k	24k	11k	59k	150k
Turkey	1.6	1.5	2.1	2.6	1.9	3.1	3.1	3.1	3.0	3.1	260k	510k	150k	100k	1.1M
Ecuador	2.0		2.5	2.6	2.2	3.1		3.1	3.1	3.1	150k		12k	17k	210k
Belarus	1.8	2.2	2.7	2.6	2.8	3.2	3.0	3.0	3.0	2.9	39k	34k	8.6k	6.7k	160k
Spain	1.2	2.1	2.6	2.6	1.8	3.2	3.0	3.0	3.0	3.1	580k	470k	130k	110k	1.4M
Kuwait	2.7	4.1	3.1	2.5	3.0	3.2	3.2	3.2	3.2	3.2	20k	10k	2k	2.5k	37k
Netherlands	1.5	2.2	2.2	2.5	1.9	3.2	3.1	3.1	3.0	3.1	260k	140k	52k	54k	500k
Turkmenistan	1.9	2.3	2.1	2.4	2.4	3.2	3.1	3.1	3.1	3.1	5k	7.1k	2.7k	3.6k	26k
Korea, Rep.	0.9	1.4	2.0	2.4	1.4	3.2	3.2	3.1	3.1	3.2	160k	120k	37k	37k	370k
Gambia, The	0.5	1.5	1.6	2.3	1.4	3.2	3.1	3.1	2.9	3.1	5.7k	5.1k	4.8k	1.6k	19k
Iraq	2.1	1.8	2.0	2.2	2.0	3.1	3.1	3.0	3.0	3.1	28k	150k	21k	110k	320k
Botswana	1.8	2.3	2.7	2.2	2.2	3.0	3.0	2.9	3.0	3.0	4.3k	20k	14k	11k	71k
Paraguay	1.1	1.5	1.6	2.1	1.4	3.3	3.2	3.2	3.2	3.2	34k	21k	9.8k	7.7k	89k
Morocco	1.5	1.9	1.9	2.0	1.9	3.2	3.1	3.1	3.1	3.1	81k	86k	29k	59k	280k
Uruguay	-0.3	0.5	1.7	2.0	0.4	3.5	3.3	3.1	3.0	3.4	24k	29k	6.9k	2.9k	66k
Mali	0.7	1.0	1.5	1.9	1.5	3.3	3.2	3.2	3.1	3.2	7.8k	33k	8.8k	28k	89k
Niger	0.2	0.6	1.3	1.8	1.4	3.3	3.3	3.2	3.2	3.2	4.2k	8.1k	4.5k	17k	46k
Sudan	0.6	1.1	1.6	1.8	1.6	3.3	3.4	3.3	3.3	3.3	64k	52k	12k	92k	320k
Japan	1.1	1.5	2.2	1.8	1.3	3.2	3.1	3.1	3.1	3.1	2.8M	990k	130k	110k	4M
Taiwan, China	1.1	2.1	2.0	1.8	1.3	3.2	3.1	3.2	3.2	3.2	130k	12k	7.9k	7.5k	160k
Mozambique	2.1	1.2	1.7	1.7	1.8	3.1	3.1	3.1	3.0	3.0	16k	33k	16k	38k	130k
Senegal	0.9	1.2	1.3	1.6	1.5	3.3	3.3	3.2	3.1	3.2	30k	47k	19k	31k	150k
South Sudan	0.9	0.6	2.4	1.6	1.9	3.4	3.4	3.4	3.3	3.3	2k	1.2k	1.1k	11k	21k
Eritrea	3.6	2.6	3.0	1.6	2.6	3.0	3.1	3.1	3.2	3.1	2.2k	1.7k	630	2.4k	18k
Peru	1.5	0.8	1.5	1.5	1.5	3.2	3.3	3.2	3.2	3.2	190k	11k	9.1k	23k	280k
Argentina	0.2	0.5	1.1	1.5	0.6	3.5	3.4	3.3	3.3	3.4	300k	310k	84k	69k	820k
Burkina Faso	0.6	1.3	1.4	1.5	1.5	3.3	3.2	3.2	3.1	3.1	16k	10k	12k	28k	74k
Belize	1.4	2.1	2.8	1.5	2.2	3.1	3.1	3.0	3.1	3.0	2.7k	1.6k	2.1k	620	9k

	Sprawl (SNDi)					Nodal degree					N(nodes)				
	<1975	75–89	90–99	2000–13	Stock	<1975	75–89	90–99	2000–13	Stock	<1975	75–89	90–99	2000–13	Stock
Bolivia	1.3	1.1	1.0	1.2	1.5	3.3	3.3	3.3	3.3	3.2	42k	34k	26k	36k	170k
Singapore	1.9		1.3	1.1	1.9	3.3		3.4	3.5	3.3	17k		380	170	18k
Chad	0.0	1.2	1.0	1.1	1.2	3.4	3.4	3.3	3.3	3.3	5.6k	3.1k	4.9k	12k	34k
Somalia	0.9	0.9	1.6	1.0	1.1	3.4	3.3	3.3	3.3	3.3	16k	16k	4.7k	19k	60k
Mauritania	0.1	0.2	0.5	0.5	0.6	3.4	3.3	3.3	3.3	3.3	5.8k	3.5k	2.1k	4.1k	26k
Maldives	-0.6			-0.3	0.7	3.3			3.3	3.0	440			280	7k

F.6 Cities ranked by urban street-network sprawl (SNDi) of recent road development

Table S2: **Cities listed in order of their recent urban street-network sprawl (SNDi).**

	Sprawl (SNDi)				Nodal degree				N(nodes)			
	<1990	90-99	'00-13	Stock	<1990	90-99	'00-13	Stock	<1990	90-99	'00-13	Stock
Suva, Fiji	3.5	8.4	10.4	8.2	2.9	2.3	2.1	2.4	150	1.4k	150	1.7k
Caracas, Venezuela	4.9	10.4	10.1	5.3	2.8	2.3	2.3	2.8	11k	770	540	12k
Bangkok, Thailand	6.8	7.6	8.1	7.3	2.5	2.5	2.4	2.5	74k	30k	46k	150k
Guatemala City, Guatemala	3.8	5.6	7.5	4.5	3.0	2.8	2.5	2.9	22k	7.3k	4.7k	34k
Cebu City, Philippines	6.1	6.9	7.3	6.6	2.6	2.5	2.6	2.6	5.7k	2.3k	4.5k	12k
Gorgan, Iran	3.6	5.8	6.7	3.9	2.7	2.5	2.4	2.7	3.3k	470	240	4k
Los Angeles, United States	3.6	6.2	6.3	3.9	2.9	2.6	2.6	2.9	250k	26k	9.7k	290k
Raleigh, United States	4.8	5.4	6.3	5.6	2.8	2.7	2.5	2.6	11k	21k	19k	51k
Palembang, Indonesia	4.7	5.6	6.3	5.2	2.6	2.5	2.5	2.6	15k	19k	3.9k	39k
New York, United States	2.9	5.2	6.3	3.1	3.0	2.7	2.5	2.9	320k	42k	3.5k	360k
San Salvador, El Salvador	4.4	7.1	6.1	5.0	2.8	2.5	2.6	2.7	11k	1.7k	4.7k	17k
Belgrade, Serbia	2.9	6.6	6.0	4.2	3.0	2.3	2.4	2.7	9.1k	2.2k	4k	15k
Tijuana, Mexico	4.3	3.6	6.0	4.4	2.9	3.0	2.7	2.9	15k	9.2k	8.5k	33k
Florianopolis, Brazil	2.9	5.9	5.9	4.1	2.9	2.5	2.6	2.8	7.2k	2.5k	3.2k	13k
Pune, India	3.4	5.0	5.9	4.9	2.8	2.6	2.5	2.7	6.3k	15k	10k	31k
Sao Paulo, Brazil	2.1	4.9	5.8	2.5	3.1	2.8	2.6	3.0	150k	23k	5.5k	180k
Medan, Indonesia	4.0	5.2	5.8	4.9	2.7	2.5	2.5	2.6	20k	29k	16k	64k
Gainesville, United States	3.0	6.4	5.6	3.8	3.1	2.7	2.8	3.0	3.9k	800	1.2k	5.8k
Johannesburg, South Africa	2.9	4.1	5.5	3.8	3.0	2.9	2.8	2.9	63k	16k	30k	110k
Dhaka, Bangladesh	3.3	4.9	5.5	4.0	2.9	2.7	2.6	2.8	14k	5.5k	6.6k	26k
Kolkata, India	3.2	4.6	5.4	3.9	2.9	2.7	2.6	2.8	20k	10k	6.4k	36k
Pematangsiantar, Indonesia	3.2	4.6	5.4	3.7	2.9	2.8	2.6	2.9	1.5k	300	280	2.1k
Ulaanbaatar, Mongolia	4.1	4.8	5.3	4.5	2.8	2.6	2.6	2.7	5.9k	1.4k	3.1k	10k
Kampala, Uganda	4.9	5.6	5.3	5.1	2.6	2.5	2.6	2.6	8.4k	3.8k	3.2k	15k
Houston, United States	2.9	5.1	5.3	3.9	3.1	2.8	2.8	2.9	88k	31k	45k	160k
Philadelphia, United States	2.3	4.9	5.2	2.8	3.1	2.8	2.7	3.0	120k	25k	15k	160k
Victoria, Canada	2.9	4.6	5.2	3.3	2.9	2.7	2.8	2.9	6.6k	1.8k	450	8.8k
Ho Chi Minh City, Viet Nam	1.8	4.2	5.2	4.6	3.2	2.8	2.6	2.7	6.1k	13k	45k	64k
Manila, Philippines	3.9	5.1	5.1	4.4	3.0	2.9	2.9	2.9	62k	26k	29k	120k
Sheffield, United Kingdom	3.4	5.1	5.1	3.5	2.8	2.5	2.5	2.7	29k	2.5k	810	32k
Rawang, Malaysia	3.5	4.7	5.0	4.7	3.0	3.0	2.9	2.9	540	820	3.8k	5.1k
Pokhara, Nepal	3.2	4.5	5.0	3.6	2.7	2.6	2.5	2.7	1.8k	280	470	2.6k
Baku, Azerbaijan	4.1	5.2	5.0	4.6	2.8	2.5	2.6	2.7	11k	7.4k	5.1k	23k

	Sprawl (SNDi)				Nodal degree				N(nodes)			
	<1990	90-99	'00-13	Stock	<1990	90-99	'00-13	Stock	<1990	90-99	'00-13	Stock
Lagos, Nigeria	4.2	4.6	5.0	4.5	2.8	2.6	2.6	2.7	24k	22k	19k	65k
Vijayawada, India	2.8	4.1	4.9	3.2	3.0	2.7	2.6	2.9	6.9k	1.4k	730	9k
Sialkot, Pakistan	2.7	4.9	4.9	4.0	3.0	2.6	2.6	2.8	1.6k	2.3k	320	4.3k
Rajshahi, Bangladesh	1.4	3.7	4.9	3.9	3.1	2.7	2.6	2.7	130	1.6k	710	2.4k
Cirebon, Indonesia	2.7	4.2	4.9	4.5	2.9	2.7	2.7	2.7	1.1k	2.3k	7.9k	11k
Portland, United States	3.0	4.9	4.8	3.4	3.0	2.7	2.7	2.9	51k	10k	6.1k	67k
Cleveland, United States	2.8	5.4	4.8	3.8	3.0	2.7	2.8	2.9	24k	9.5k	14k	47k
Tyumen, Russia	1.7	4.5	4.8	3.0	3.3	2.8	2.8	3.1	2.3k	920	1.2k	4.4k
Mexico City, Mexico	1.8	4.0	4.8	2.7	3.2	2.8	2.7	3.0	120k	32k	40k	190k
Algiers, Algeria	3.9	3.8	4.7	4.1	2.9	2.9	2.8	2.9	12k	10k	8.9k	31k
Minneapolis, United States	2.8	4.6	4.7	3.3	3.1	2.8	2.7	3.0	63k	14k	11k	88k
Kaunas, Lithuania	2.2	5.3	4.7	2.7	3.2	2.7	2.8	3.1	3.2k	170	680	4k
Coimbatore, India	3.5	4.2	4.7	3.9	2.8	2.8	2.7	2.8	7.2k	5.3k	3.4k	16k
Arusha, Tanzania	1.4	4.5	4.7	3.6	3.1	2.6	2.7	2.8	270	400	250	910
Manchester, United Kingdom	4.0	5.2	4.6	4.0	2.7	2.5	2.6	2.7	71k	2.5k	220	74k
Springfield, United States	3.0	4.7	4.6	3.7	2.9	2.8	2.7	2.9	9.6k	7.1k	2.2k	19k
Mumbai, India	3.3	4.3	4.6	3.7	2.9	2.8	2.7	2.8	23k	2.5k	8.4k	34k
Astrakhan, Russia	2.0	3.5	4.6	2.5	3.1	2.8	2.6	3.0	3.7k	2.4k	150	6.2k
Toledo, United States	2.1	4.2	4.6	2.8	3.2	2.9	2.8	3.0	9.9k	3.4k	2.8k	16k
Kozhikode, India	1.7	3.8	4.5	3.5	3.0	2.7	2.6	2.7	340	530	970	1.8k
Parepare, Indonesia	2.4	3.8	4.4	3.3	3.0	2.7	2.7	2.8	750	300	520	1.6k
Guadalajara, Mexico	1.7	3.8	4.4	2.5	3.2	3.0	2.9	3.1	46k	8.8k	21k	75k
Chicago, United States	2.6	4.6	4.4	2.9	3.1	2.8	2.8	3.0	170k	30k	13k	210k
Jequie, Brazil	1.2	1.9	4.4	1.5	3.2	3.1	2.9	3.2	2.4k	840	240	3.4k
Santiago, Chile	1.5	2.1	4.4	1.9	3.1	3.1	2.9	3.1	66k	14k	13k	93k
Cabimas, Venezuela	2.4	2.8	4.3	2.6	2.9	3.0	2.7	2.9	6.4k	1.3k	700	8.4k
Tashkent, Uzbekistan	2.7	4.3	4.3	3.3	3.0	2.8	2.7	2.9	17k	8.6k	4.1k	30k
Bacolod, Philippines	2.6	5.1	4.3	4.2	3.1	2.9	3.1	3.0	1.1k	1.7k	870	3.7k
Ipoh, Malaysia	3.6	4.4	4.3	3.8	2.9	2.8	2.9	2.9	11k	3.3k	1.5k	16k
Ahvaz, Iran	1.8	3.7	4.3	2.4	3.2	2.8	2.8	3.1	9.2k	2.3k	1.8k	13k
Killeen, United States	2.7	3.5	4.3	3.4	3.0	2.9	2.8	2.9	4.1k	710	3.2k	8k
Singrauli, India	4.7	4.0	4.3	4.2	2.8	2.9	2.9	2.9	220	780	420	1.4k
Accra, Ghana	3.3	3.5	4.2	3.9	2.9	2.8	2.7	2.8	7.9k	18k	31k	57k
Sydney, Australia	3.0	5.2	4.2	3.3	2.9	2.7	2.9	2.9	61k	7.8k	7.8k	76k
Bogota, Colombia	1.2	2.0	4.2	1.3	3.2	3.1	2.8	3.2	44k	4.7k	1.1k	50k
Quito, Ecuador	1.9	4.0	4.1	3.3	3.1	2.9	2.8	2.9	10k	6k	16k	32k

	Sprawl (SNDi)				Nodal degree				N(nodes)			
	<1990	90-99	'00-13	Stock	<1990	90-99	'00-13	Stock	<1990	90-99	'00-13	Stock
Moscow, Russia	1.3	3.3	4.1	2.2	3.4	3.0	2.9	3.2	30k	11k	13k	54k
Ibadan, Nigeria	4.1	3.7	4.1	4.0	2.7	2.8	2.7	2.7	20k	12k	16k	47k
Belo Horizonte, Brazil	1.5	3.7	4.1	1.8	3.2	2.9	2.9	3.2	42k	4.7k	2.8k	50k
London, United Kingdom	3.3	4.3	4.1	3.4	2.8	2.7	2.7	2.8	150k	25k	2.8k	180k
Saidpur, Bangladesh	2.7		4.0	3.2	2.8		2.6	2.8	270	19	130	420
Istanbul, Turkey	1.0	1.6	4.0	1.5	3.2	3.2	2.8	3.2	76k	48k	21k	140k
Warsaw, Poland	1.5	2.5	4.0	2.2	3.3	3.0	2.7	3.1	17k	6.9k	5.3k	29k
Curitiba, Brazil	1.8	3.0	4.0	2.4	3.2	3.0	2.8	3.1	23k	15k	6.8k	45k
Sana, Yemen	1.1	2.5	4.0	1.5	3.2	3.0	2.8	3.1	9.2k	1.1k	1.1k	11k
Tehran, Iran	2.4	3.5	3.9	2.6	3.0	2.9	2.8	2.9	63k	11k	7.7k	82k
Hyderabad, India	2.6	3.1	3.8	3.1	2.9	2.9	2.8	2.9	53k	41k	43k	140k
Halle, Germany	1.1	2.9	3.8	1.5	3.3	3.0	2.8	3.2	2.9k	960	180	4.1k
Modesto, United States	3.1	3.6	3.7	3.4	2.9	2.8	2.8	2.8	7.3k	3.2k	2.6k	13k
Rovno, Ukraine	2.3	3.1	3.7	3.0	3.1	2.8	2.8	2.9	930	250	1.3k	2.5k
Milan, Italy	1.9	3.6	3.7	2.9	3.1	2.8	2.7	2.9	58k	48k	31k	140k
Lausanne, Switzerland	1.3	2.7	3.7	1.8	3.4	3.1	2.8	3.2	2.6k	1.1k	290	4.1k
Haikou, China	2.8	2.6	3.7	3.0	3.1	3.1	2.9	3.0	1.2k	460	1k	2.6k
Hong Kong, China	0.7	1.7	3.7	0.9	3.4	3.3	3.0	3.4	5.1k	820	220	6.1k
Auckland, New Zealand	3.2	4.0	3.7	3.3	2.9	2.9	3.0	2.9	17k	1.8k	1.7k	20k
Osaka, Japan	1.2	2.8	3.7	1.3	3.2	3.0	2.9	3.2	160k	12k	2.7k	180k
Kabul, Afghanistan	3.6	3.7	3.6	3.6	2.8	2.8	2.8	2.8	12k	1.9k	7k	21k
Qom, Iran	1.9	2.3	3.6	2.2	3.1	3.1	2.9	3.0	7.2k	1.7k	2.2k	11k
Malatya, Turkey	1.1	2.6	3.6	1.6	3.2	3.0	2.8	3.1	3.8k	730	830	5.3k
Jaipur, India	2.6	3.1	3.6	3.1	3.0	2.9	2.8	2.9	8.6k	19k	13k	40k
Nakuru, Kenya	1.8	3.5	3.5	2.5	3.1	2.9	2.8	3.0	820	180	650	1.6k
Shymkent, Kazakhstan	3.6	3.3	3.5	3.5	2.9	2.9	2.9	2.9	4.3k	830	4.4k	9.5k
Kigali, Rwanda	3.0	3.3	3.5	3.3	3.0	2.9	2.9	2.9	980	1.9k	1.7k	4.6k
Culiacan, Mexico	0.7	2.0	3.5	1.5	3.4	3.2	3.0	3.3	8.2k	3.6k	3.5k	15k
Beira, Mozambique	2.5	4.5	3.5	3.2	3.0	2.9	2.8	2.9	1.3k	110	2k	3.4k
Tangshan, China	2.9	3.1	3.4	3.3	3.0	3.0	2.8	2.9	1.7k	870	3.1k	5.6k
Tel Aviv, Israel	1.1	2.5	3.4	2.0	3.2	3.1	3.0	3.1	9.6k	14k	4.2k	28k
Hindupur, India			3.4	2.7			3.0	3.0	32	42	250	320
Myeik, Myanmar	1.9	3.3	3.3	2.4	3.1	2.8	2.8	3.0	720	140	500	1.4k
Palermo, Italy	2.2	6.4	3.3	2.6	3.0	2.5	2.8	2.9	7.1k	220	3.5k	11k
Montreal, Canada	1.8	3.5	3.3	1.9	3.3	3.0	3.1	3.2	45k	2.4k	4.7k	52k
Port Elizabeth, South Africa	2.3	4.2	3.3	2.7	3.0	2.8	3.0	3.0	9.1k	990	6.3k	16k

	Sprawl (SNDi)				Nodal degree				N(nodes)			
	<1990	90-99	'00-13	Stock	<1990	90-99	'00-13	Stock	<1990	90-99	'00-13	Stock
Paris, France	1.8	3.0	3.3	2.0	3.1	2.9	2.8	3.1	120k	13k	11k	140k
Alexandria, Egypt	0.7	2.3	3.3	1.1	3.3	3.0	2.9	3.2	8.2k	1.2k	1.8k	11k
Antwerp, Belgium	1.5	2.8	3.2	1.9	3.2	2.9	2.8	3.1	16k	6.2k	1.1k	23k
Ahmedabad, India	2.5	3.5	3.2	2.7	3.0	2.8	2.9	2.9	8.9k	1.5k	1.5k	12k
Saint Petersburg, Russia	0.5	3.4	3.2	1.9	3.6	2.9	3.0	3.3	9.6k	3.6k	6.8k	20k
Palmas, Brazil	3.1	3.5	3.2	3.3	3.1	2.9	3.1	3.0	1.2k	3k	1.1k	5.3k
Lahore, Pakistan	2.3	2.8	3.2	2.5	3.0	2.9	3.0	3.0	25k	6k	8.7k	40k
Oyo, Nigeria	3.4	3.4	3.2	3.3	2.7	2.8	2.8	2.8	1.5k	780	2.3k	4.5k
Kinshasa, DR Congo	2.1	3.2	3.2	2.7	3.2	3.0	2.9	3.1	19k	13k	15k	46k
Shanghai, China	1.6	2.9	3.1	2.1	3.3	3.1	3.1	3.2	22k	10k	4.3k	36k
Zunyi, China	3.6	3.4	3.1	3.3	2.9	3.0	3.1	3.0	450	210	400	1.1k
Seoul, South Korea	0.9	2.3	3.1	1.2	3.2	3.1	3.0	3.2	87k	23k	15k	130k
Guixi, China	1.3		3.1	2.5	3.0		2.8	2.9	120	98	150	370
Vienna, Austria	0.5	2.3	3.0	1.0	3.4	3.0	2.9	3.3	16k	5.9k	1.5k	23k
Tebessa, Algeria	2.0	2.6	3.0	2.2	3.1	3.1	2.9	3.1	2.5k	850	370	3.8k
Shenzhen, China	2.5	2.6	3.0	2.7	3.1	3.1	3.0	3.1	6.8k	10k	5.6k	23k
Reynosa, Mexico	1.9	2.9	3.0	2.2	3.2	3.2	3.0	3.2	7.5k	720	3k	11k
Oldenburg, Germany	2.0	3.0	3.0	2.2	3.2	3.0	2.9	3.1	2.5k	670	400	3.5k
Guangzhou, China	1.8	2.8	2.9	2.8	3.2	3.0	3.0	3.0	5.6k	34k	33k	73k
Baghdad, Iraq	2.1	3.3	2.9	2.2	3.1	2.8	2.9	3.1	45k	800	1.1k	47k
Gomel, Belarus	1.6	2.4	2.9	2.0	3.3	3.0	2.9	3.1	1.4k	1.1k	190	2.7k
Riyadh, Saudi Arabia	1.7	2.7	2.9	2.1	3.2	3.1	3.1	3.1	50k	14k	26k	90k
Qingdao, China	1.6	1.0	2.8	2.4	3.2	3.2	3.0	3.0	2.7k	2.3k	14k	19k
Singapore, Singapore	1.9	1.5	2.8	1.9	3.3	3.4	3.2	3.3	14k	2.3k	620	17k
Cochabamba, Bolivia	0.6	2.2	2.8	1.6	3.4	3.1	3.0	3.2	9.5k	6.2k	5.8k	21k
Cairo, Egypt	1.4	2.2	2.7	2.1	3.2	3.1	3.1	3.1	23k	5.1k	33k	62k
Cordoba, Argentina	0.6	2.3	2.7	1.0	3.4	3.2	3.1	3.3	22k	2.4k	4.5k	29k
Xingping, China	2.4		2.7	2.5	3.0		2.9	2.9	110	34	260	410
Beijing, China	2.0	2.7	2.7	2.3	3.2	3.1	3.1	3.1	19k	4.6k	15k	39k
Bukhara, Uzbekistan	0.9	2.9	2.7	2.5	3.3	2.9	2.9	2.9	380	910	1.3k	2.6k
Belgaum, India	1.2	2.1	2.7	2.2	3.1	3.1	3.0	3.1	560	740	1.5k	2.8k
Taipei, China	0.4	1.9	2.6	1.2	3.4	3.1	3.0	3.2	15k	9.3k	7.7k	33k
Yulin, China	2.7	2.1	2.5	2.7	2.9	3.1	2.9	3.0	210	320	300	820
Bicheng, China	0.2	0.4	2.5	1.7	3.3	3.3	3.1	3.1	150	130	630	910
Zwolle, Netherlands	2.0	1.6	2.5	1.9	3.1	3.3	3.0	3.1	3.1k	470	200	3.7k
Tianjin, China	1.7	2.9	2.5	2.3	3.3	3.1	3.1	3.1	5k	1.2k	14k	20k

	Sprawl (SNDi)				Nodal degree				N(nodes)			
	<1990	90-99	'00-13	Stock	<1990	90-99	'00-13	Stock	<1990	90-99	'00-13	Stock
Yucheng, China	3.0	2.8	2.5	2.8	2.9	2.8	2.9	2.9	310	290	250	850
Hangzhou, China	1.1	1.9	2.5	2.0	3.4	3.3	3.1	3.2	2.7k	7.9k	11k	22k
Kayseri, Turkey	1.2	1.4	2.5	1.7	3.2	3.2	3.0	3.1	1.7k	6.6k	4.1k	12k
Chengdu, China	2.0	2.9	2.4	2.5	3.1	3.1	3.1	3.1	4.5k	6.7k	10k	21k
Yamaguchi, Japan	2.5	2.5	2.4	2.5	2.9	3.1	3.0	2.9	11k	850	240	12k
Ndola, Zambia	2.1	2.2	2.4	2.1	3.0	3.0	2.9	3.0	2.7k	980	450	4.2k
Wuhan, China	2.0	2.4	2.3	2.3	3.1	3.1	3.0	3.1	5.5k	2k	7.9k	15k
Leshan, China	0.6	1.5	2.3	1.4	3.2	3.1	3.0	3.1	200	190	200	590
Yiyang, China	1.1	1.9	2.3	1.8	3.3	3.2	3.0	3.1	270	200	260	730
Karachi, Pakistan	1.8	1.4	2.3	1.8	3.2	3.2	3.2	3.2	20k	9k	7.5k	36k
Changzhou, China	1.6	1.9	2.3	2.0	3.2	3.2	3.2	3.2	810	2k	2.9k	5.7k
Le Mans, France	1.6	2.7	2.3	1.7	3.2	3.2	3.0	3.2	4.2k	130	490	4.8k
Okayama, Japan	1.6	2.4	2.3	1.6	3.1	3.1	3.1	3.1	51k	1.6k	3.4k	56k
Zhengzhou, China	2.4	2.3	2.2	2.4	3.2	3.2	3.2	3.2	2.9k	1.1k	5.4k	9.4k
Budapest, Hungary	0.5	1.3	2.2	1.2	3.4	3.1	3.0	3.2	20k	640	14k	34k
Changzhi, China	0.8	3.3	2.2	1.8	3.4	3.1	3.0	3.2	370	180	310	860
Zhuji, China	1.3	2.1	2.1	1.8	3.1	3.1	3.0	3.1	900	800	340	2k
Addis Ababa, Ethiopia	2.6	2.2	2.1	2.3	2.9	3.1	3.1	3.0	16k	11k	16k	43k
Ribeirao Preto, Brazil	1.1	3.0	2.1	1.4	3.3	3.0	3.1	3.3	9.3k	1.6k	1.5k	12k
Berlin, Germany	0.3	1.0	2.1	0.9	3.5	3.3	3.1	3.3	18k	11k	11k	40k
Thessaloniki, Greece	0.1	1.9	2.1	0.5	3.4	3.2	3.1	3.3	11k	1.2k	2.5k	14k
Fukuoka, Japan	1.1	1.8	2.0	1.2	3.2	3.1	3.1	3.2	47k	6.7k	2.7k	56k
Gombe, Nigeria	1.6	3.7	2.0	2.0	3.2	2.9	3.1	3.1	1.8k	560	4.5k	6.9k
Valledupar, Colombia	-0.2	0.6	2.0	0.2	3.5	3.4	3.2	3.5	3k	1.1k	650	4.8k
Gwangju, South Korea	0.4	1.3	1.9	0.9	3.4	3.2	3.2	3.3	5.3k	2.7k	2.3k	10k
Anqing, China	0.5		1.9	1.0	3.3		3.1	3.2	200	96	260	560
Busan, South Korea	1.3	1.6	1.8	1.4	3.2	3.1	3.2	3.2	16k	4.1k	4.2k	24k
Gaoyou, China			1.8	1.8			3.1	3.1	83	32	150	260
Kanpur, India	2.1	3.2	1.8	2.1	3.0	2.9	3.1	3.0	4.6k	440	420	5.5k
Tokyo, Japan	1.1	1.6	1.8	1.1	3.2	3.1	3.1	3.1	660k	38k	97k	800k
Marrakesh, Morocco	1.1	1.5	1.7	1.3	3.2	3.2	3.2	3.2	6.3k	2.2k	3.6k	12k
Leon, Nicaragua	1.0	3.2	1.7	1.5	3.3	2.9	3.1	3.2	1.1k	380	390	1.9k
Madrid, Spain	0.7	1.5	1.7	1.1	3.4	3.3	3.2	3.3	28k	12k	15k	55k
Buenos Aires, Argentina	-0.1	0.9	1.6	0.3	3.6	3.5	3.3	3.5	120k	17k	26k	160k
Suining, China			1.6	1.0			3.2	3.3	51	61	120	230
Bamako, Mali	0.6	1.0	1.6	1.1	3.3	3.2	3.1	3.2	13k	7.5k	16k	36k

	Sprawl (SNDi)				Nodal degree				N(nodes)			
	<1990	90-99	'00-13	Stock	<1990	90-99	'00-13	Stock	<1990	90-99	'00-13	Stock
Jinju, South Korea	0.8	2.4	1.6	1.2	3.3	3.2	3.1	3.2	2.5k	120	2.5k	5.1k
Luanda, Angola	2.0	2.2	1.5	1.8	3.0	3.0	3.1	3.1	12k	10k	28k	51k
Cheonan, South Korea	0.2	0.7	1.3	0.8	3.4	3.4	3.2	3.3	1.6k	1.2k	2.6k	5.3k
Vinh Long, Viet Nam			1.3	1.4			3.1	3.2	72	99	160	330
Lubumbashi, DR Congo	1.7	1.8	1.3	1.5	3.1	3.0	3.1	3.1	6.7k	2.3k	7.7k	17k
Jinan, China	1.8	1.5	1.2	1.7	3.2	3.3	3.3	3.2	4.3k	620	990	5.9k
Yanggu, China			0.7	0.4			3.3	3.4	79	66	130	280
Khartoum, Sudan	0.2	0.6	0.7	0.5	3.4	3.3	3.3	3.3	56k	14k	38k	110k
Xucheng, China			0.5	0.8			3.6	3.5	12	51	260	330

F.7 City maps

Maps for a number of cities are available as a ~ 300 MB PDF at:

http://sprawl.research.mcgill.ca/publications/2020-PNAS-sprawl/cities

A higher resolution version of the map for Seoul (included in the main text) is available at http://sprawl.research.mcgill.ca/publications/2020-PNAS-sprawl/SI/fig3-ts-citymap-Seoul.png

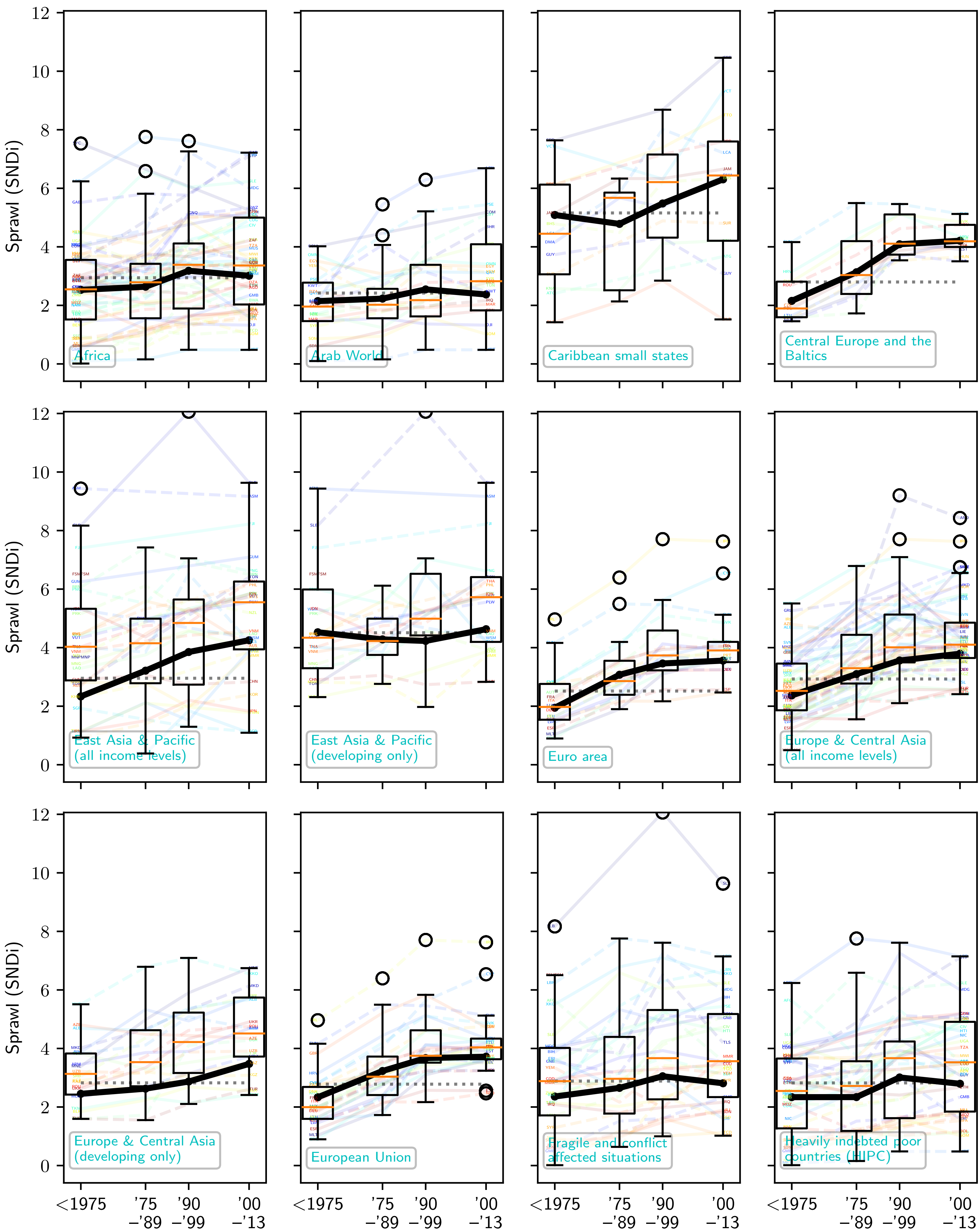
F.8 World maps

World maps for our sprawl metrics are available on an interactive map site

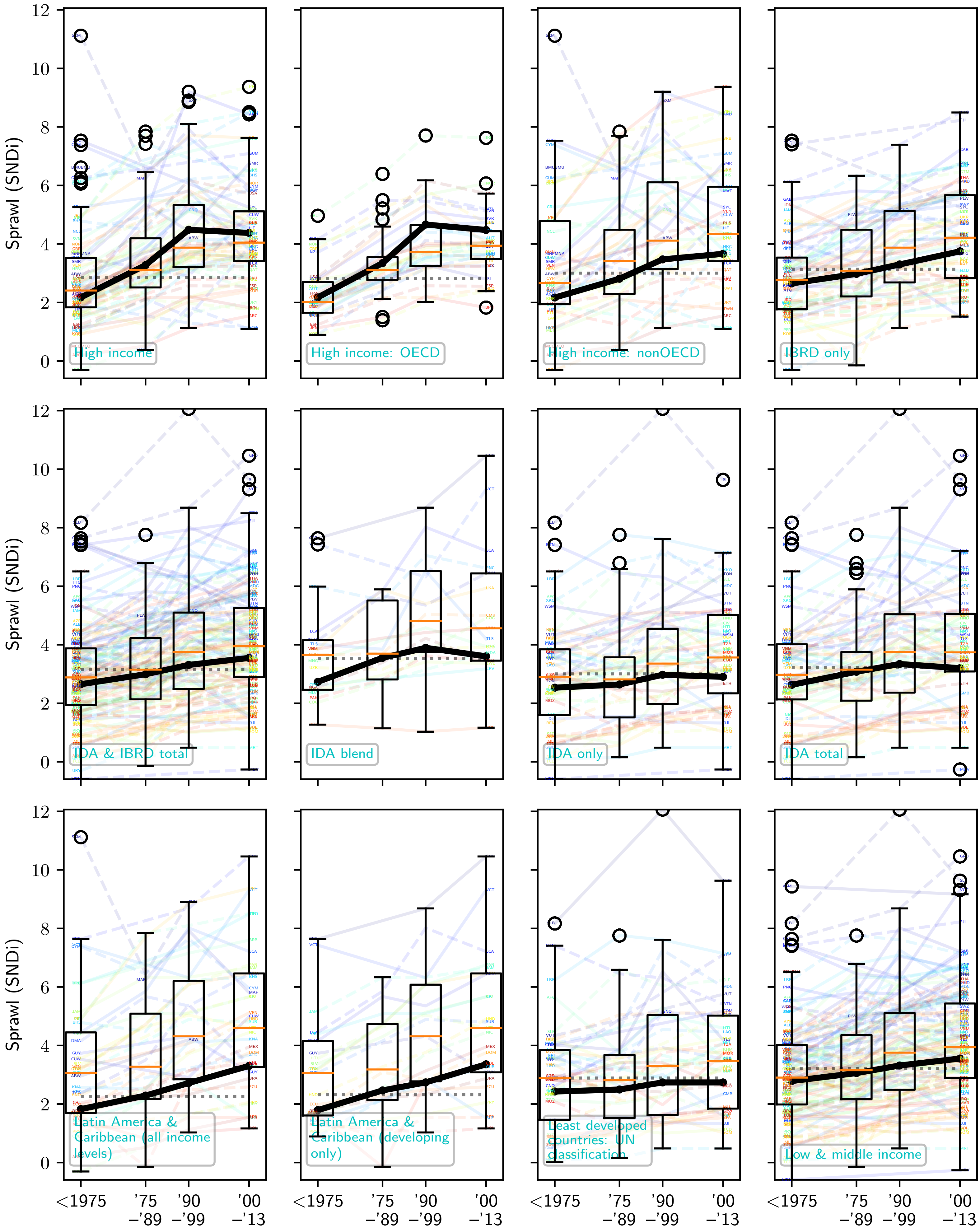
F.9 World region trend plots

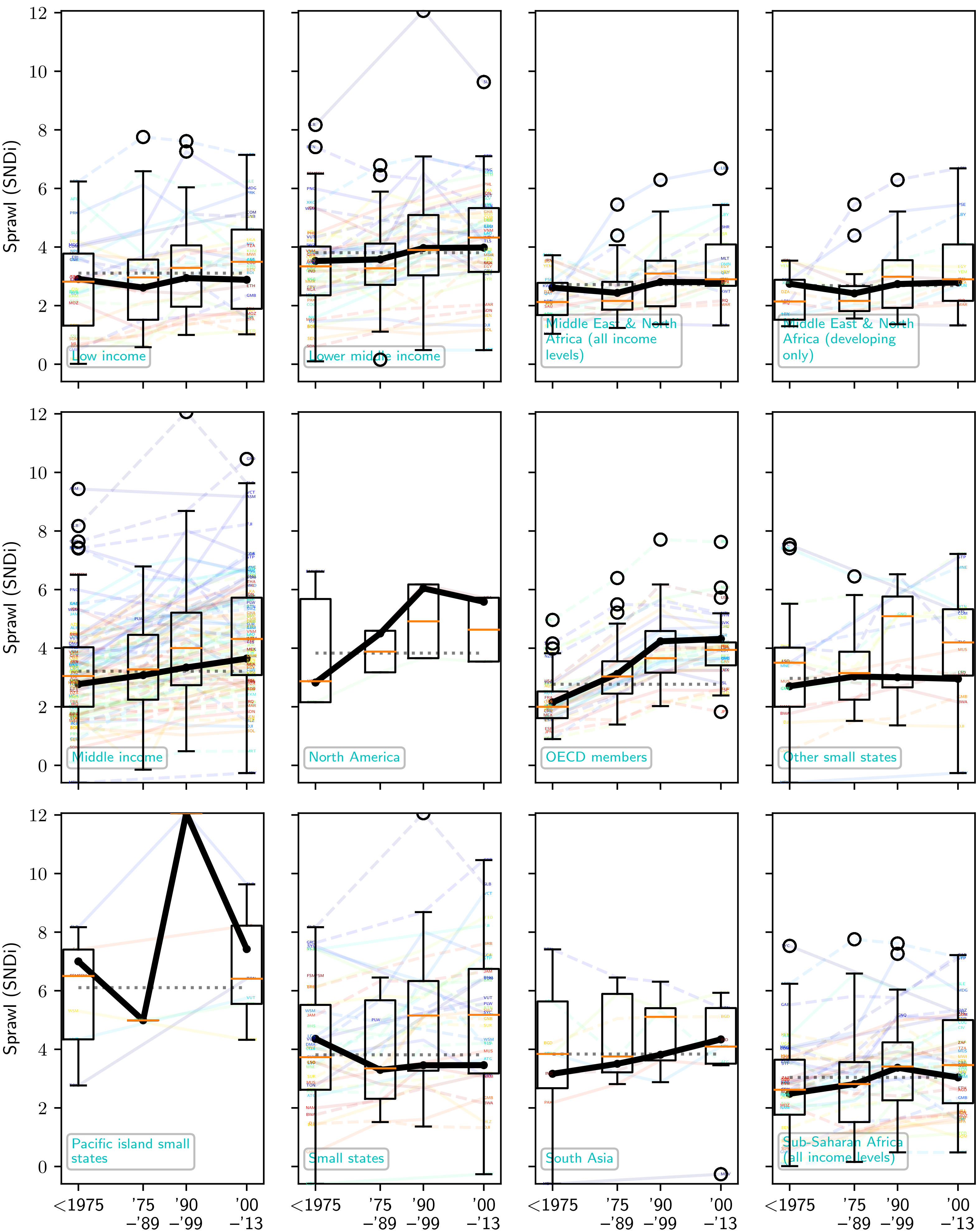
In the following pages, trends of individual countries (in each region or group) are represented by colored lines, and their distribution in each time range is summarized in a box plot. Each dotted line shows the latest stock value for all nodes in the group of countries. Country ISO codes are marked in microfont. Region classifications are from the World Bank [2016]. For more detail, see the tabular data.

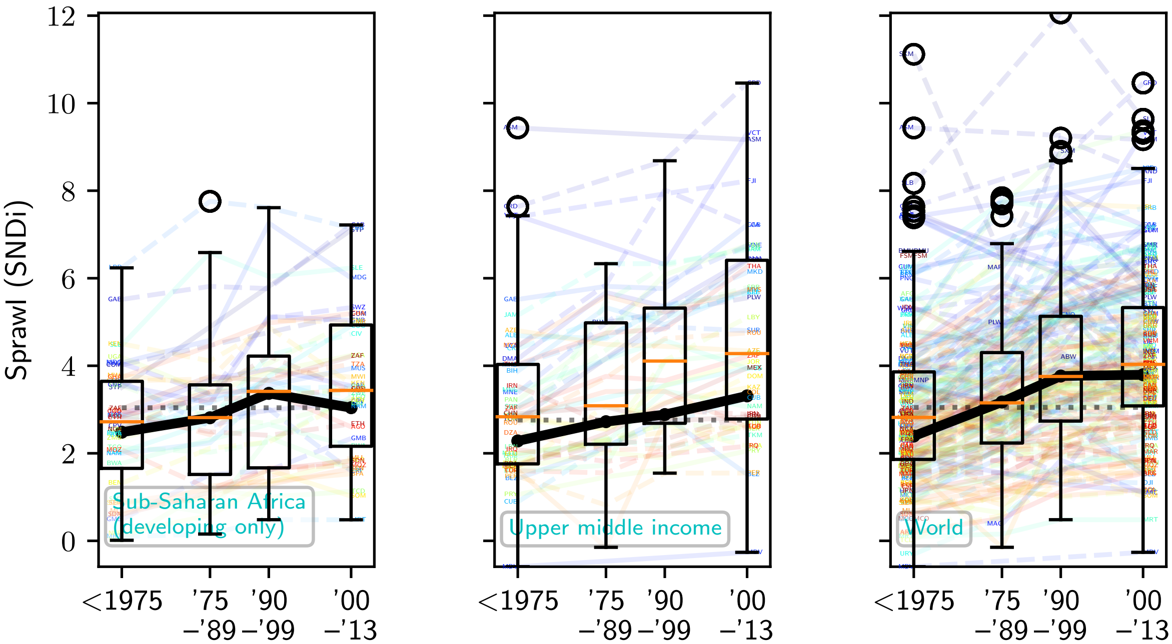
The following pages show results only for SNDi. Other metrics are available online at: https://alum.mit.edu/www/cpbl/publications/2020-PNAS-sprawl.



Sprawl (SNDi)
Africa
Arab World
Caribbean small states
Central Europe and the Baltics
East Asia & Pacific (all income levels)
East Asia & Pacific (developing only)
Euro area
Europe & Central Asia (all income levels)
Europe & Central Asia (developing only)
European Union
Fragile and conflict affected situations
Heavily indebted poor countries (HIPC)
<1975
'75 –'89
'90 –'99
'00 –'13


Sprawl (SNDi)
High income
High income: OECD
High income: nonOECD
IBRD only
IDA & IBRD total
IDA blend
IDA only
IDA total
Latin America & Caribbean (all income levels)
Latin America & Caribbean (developing only)
Least developed countries: UN classification
Low & middle income
<1975
'75 –'89
'90 –'99
'00 –'13


Sprawl (SNDi)
Low income
Lower middle income
Middle East & North Africa (all income levels)
Middle East & North Africa (developing only)
Middle income
North America
OECD members
Other small states
Pacific island small states
Small states
South Asia
Sub-Saharan Africa (all income levels)
<1975
'75 –'89
'90 –'99
'00 –'13
0
2
4
6
8
10
12

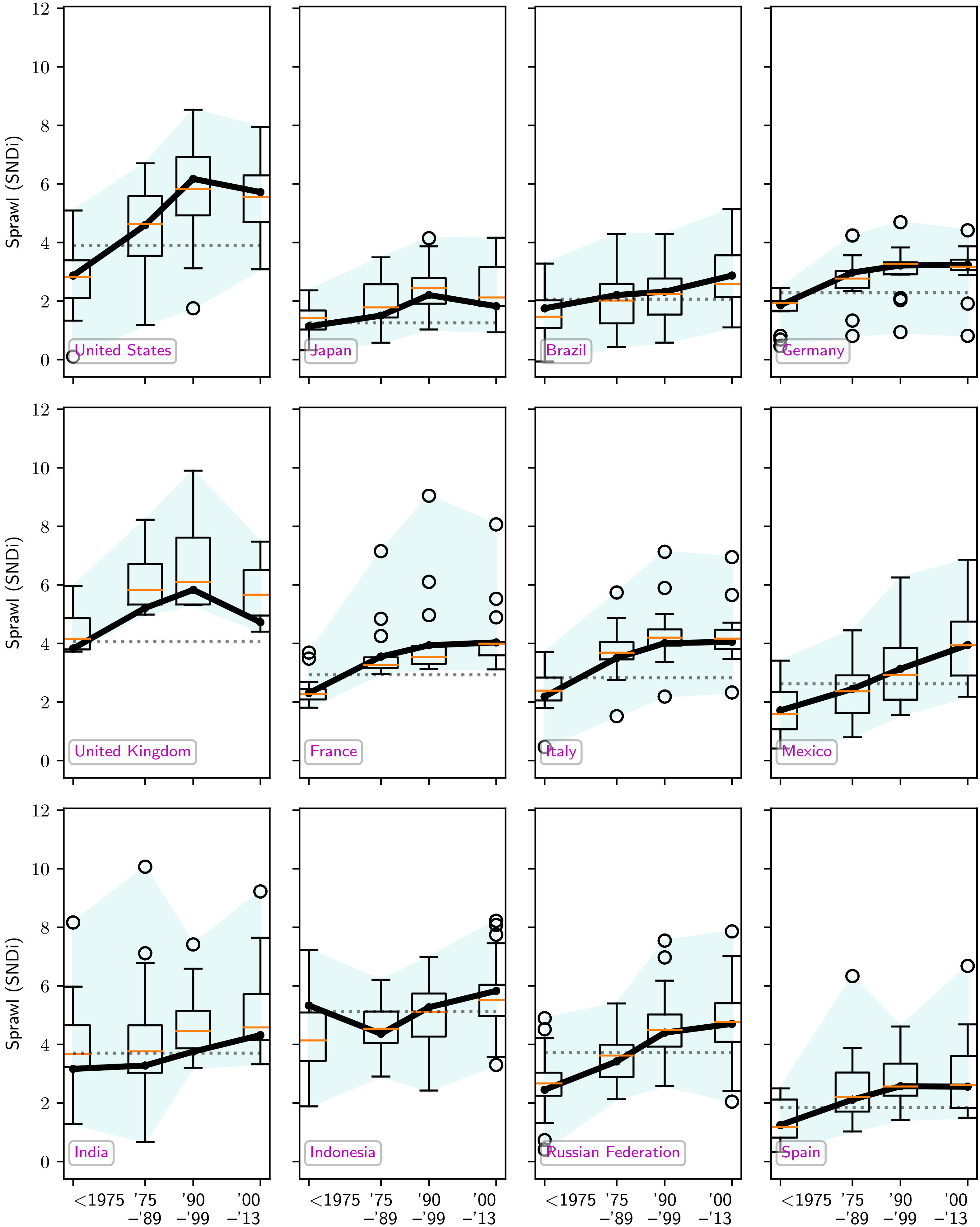


Sprawl (SNDi)
Sub-Saharan Africa (developing only)
Upper middle income
World
<1975
'75 –'89
'90 –'99
'00 –'13

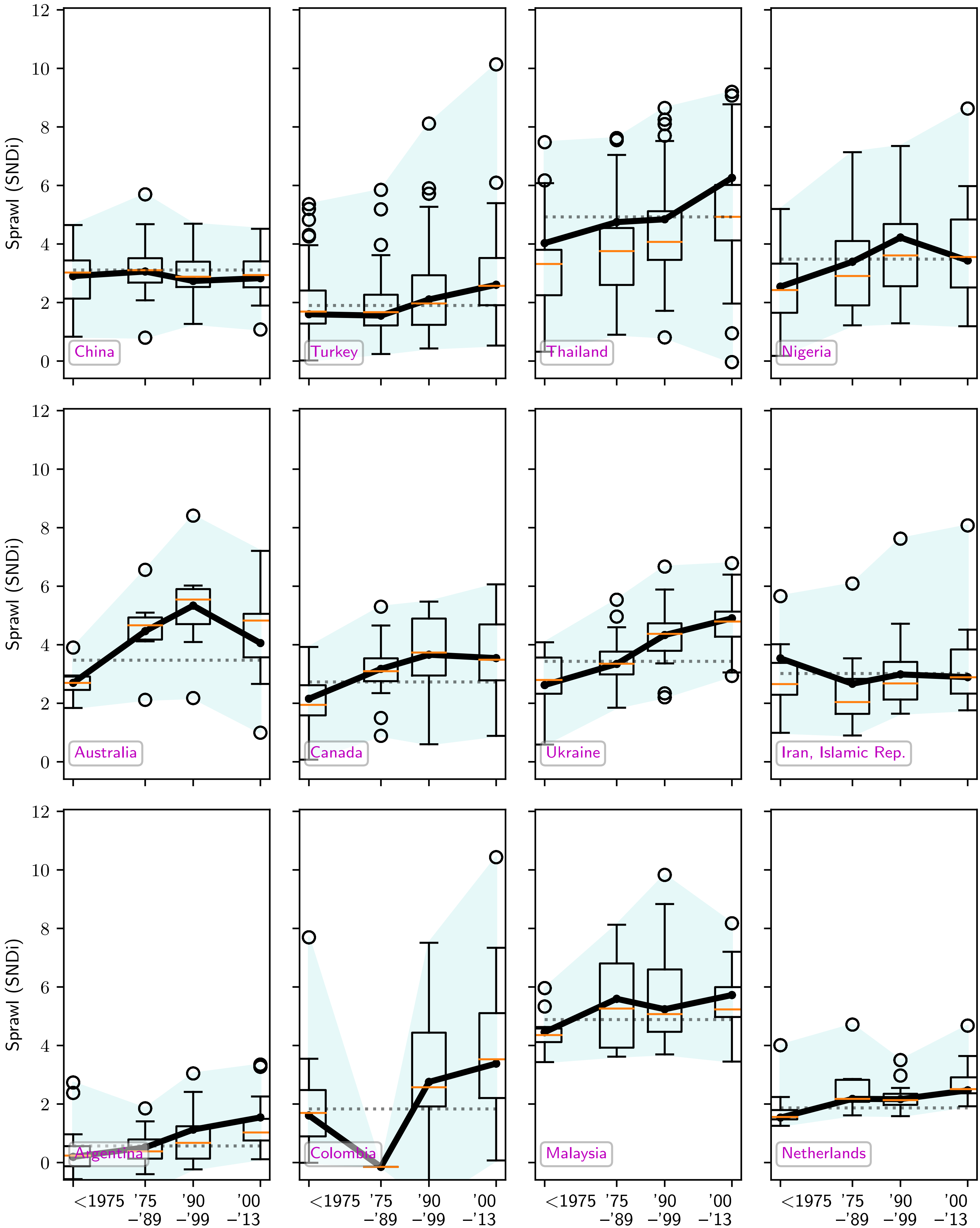
F.10 Country trend plots with sub-national regional distributions

In the following pages, box plots are used to describe the distribution, within each time period in each country, of the metric over sub-national regions (i.e., GADM level 1). The blue shaded region shows the full extent of the minimum and maximum value across these sub-national regions. The dark line shows the mean over the entire country.

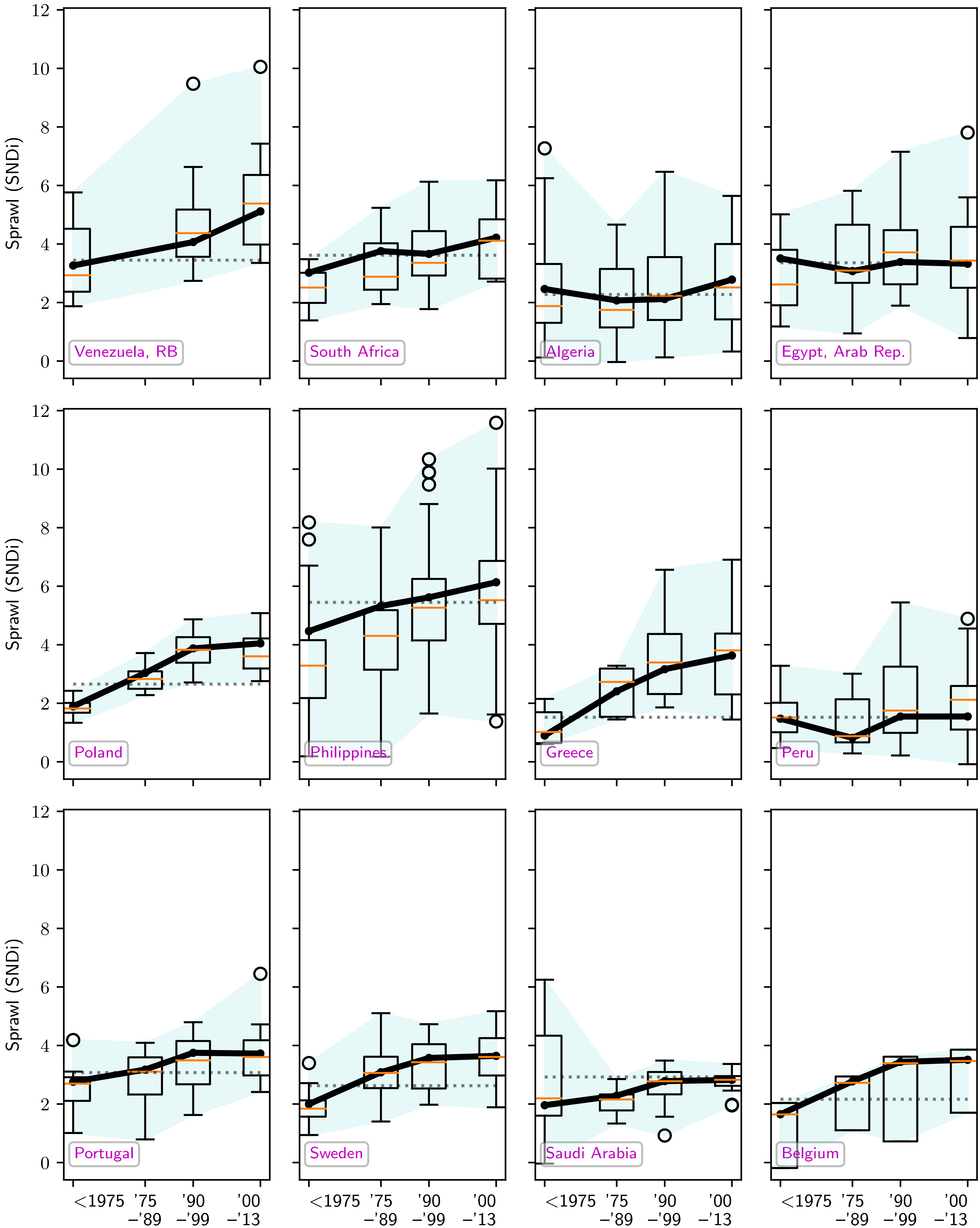
The following pages show results only for SNDi. Other metrics are available online at: https://alum.mit.edu/www/cpbl/publications/2020-PNAS-sprawl.



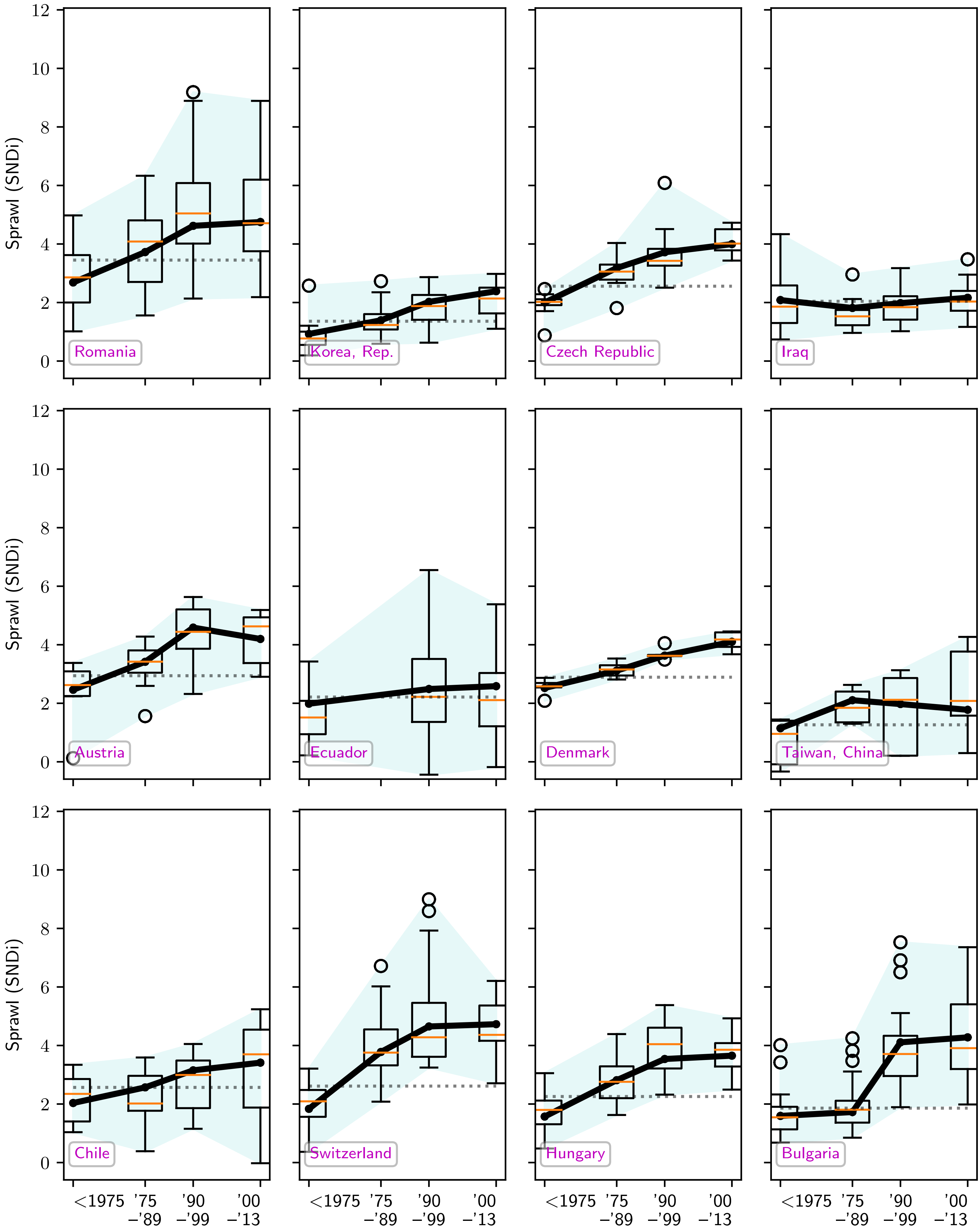
Sprawl (SNDi)
0
2
4
6
8
10
12
United States
Japan
Brazil
Germany
United Kingdom
France
Italy
Mexico
India
Indonesia
Russian Federation
Spain
<1975
'75 –'89
'90 –'99
'00 –'13



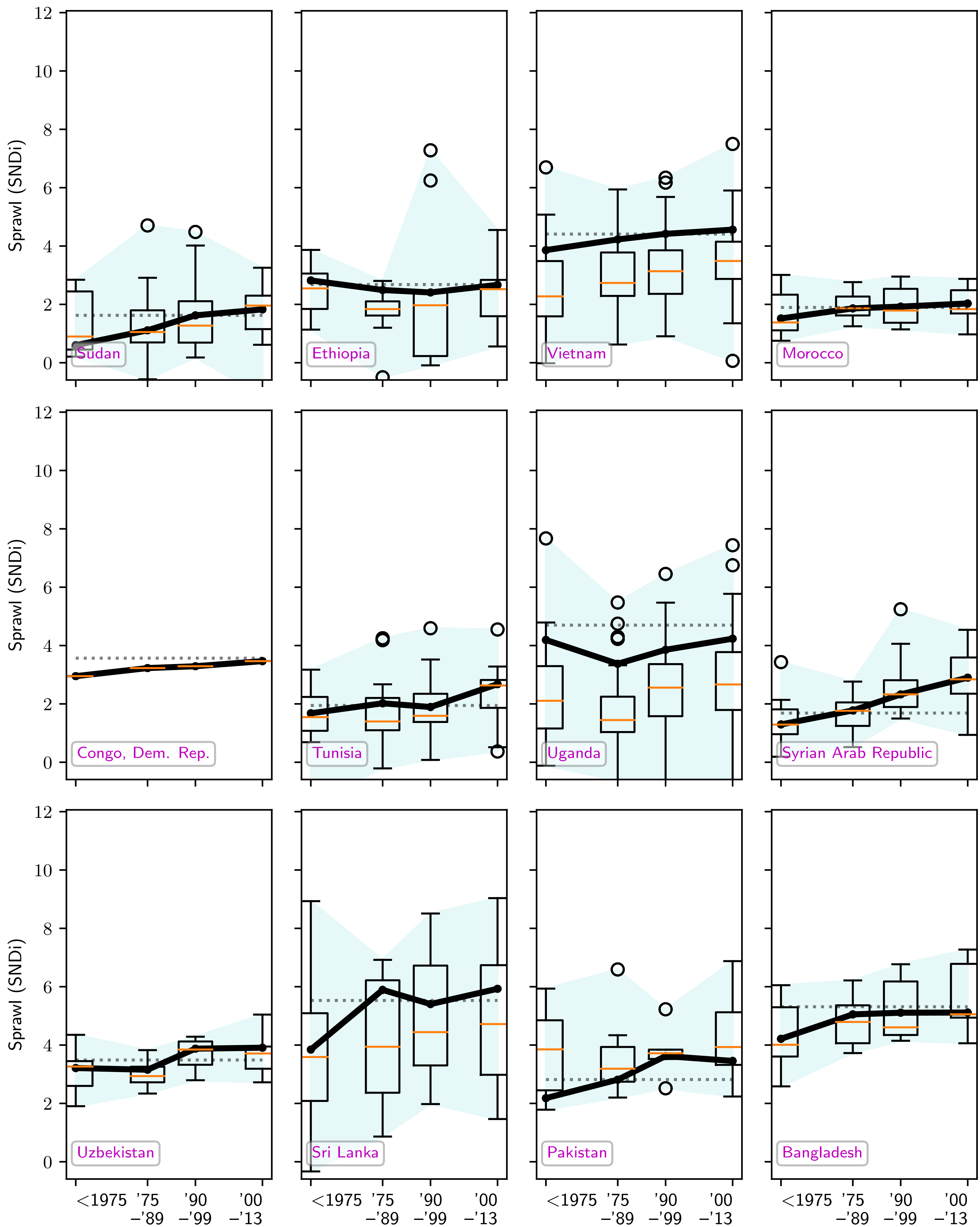
Sprawl (SNDi)
China
Turkey
Thailand
Nigeria
Australia
Canada
Ukraine
Iran, Islamic Rep.
Argentina
Colombia
Malaysia
Netherlands
<1975
'75 –'89
'90 –'99
'00 –'13



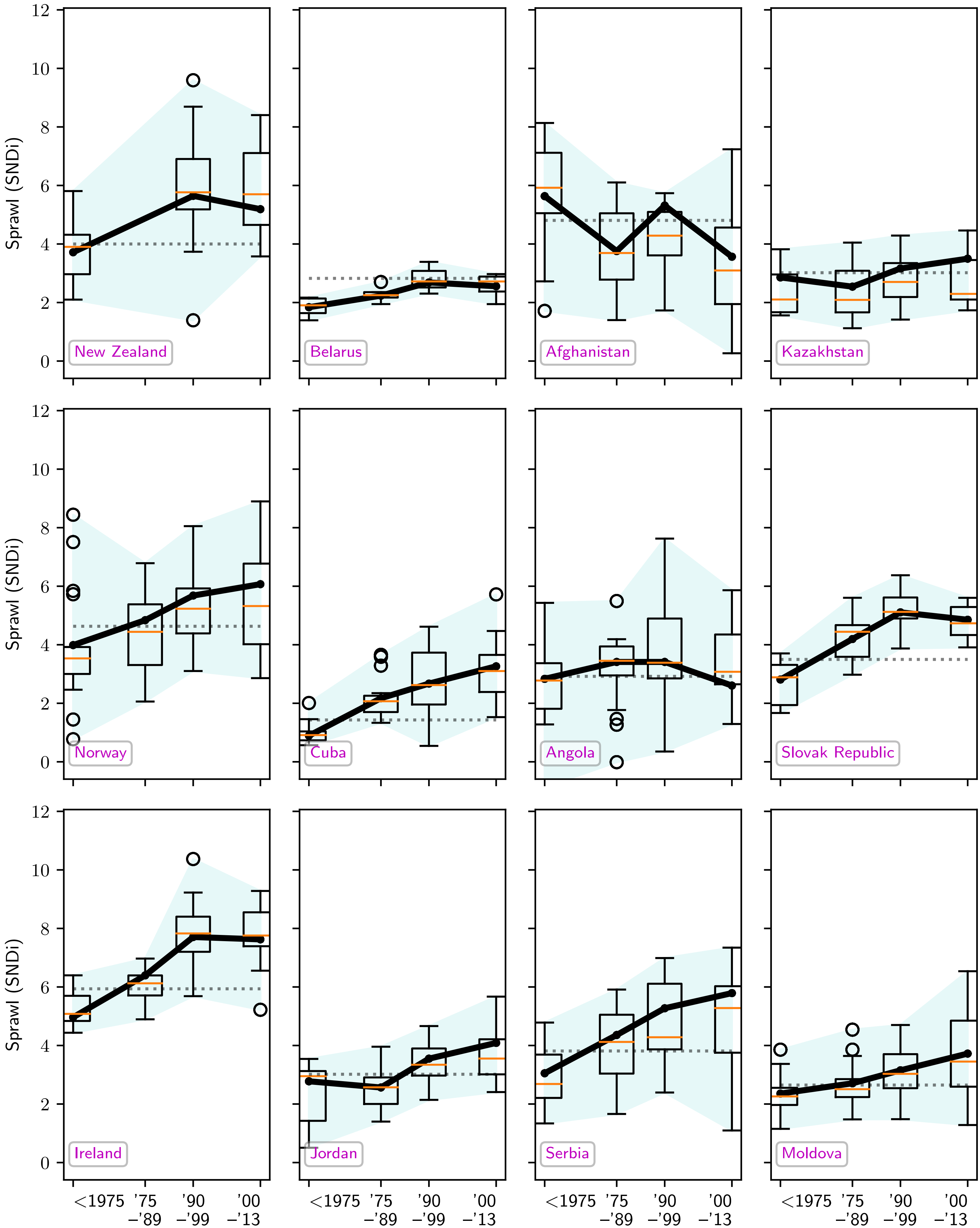
Sprawl (SNDi)
Venezuela, RB
South Africa
Algeria
Egypt, Arab Rep.
Poland
Philippines
Greece
Peru
Portugal
Sweden
Saudi Arabia
Belgium
0
2
4
6
8
10
12
<1975
'75 –'89
'90 –'99
'00 –'13



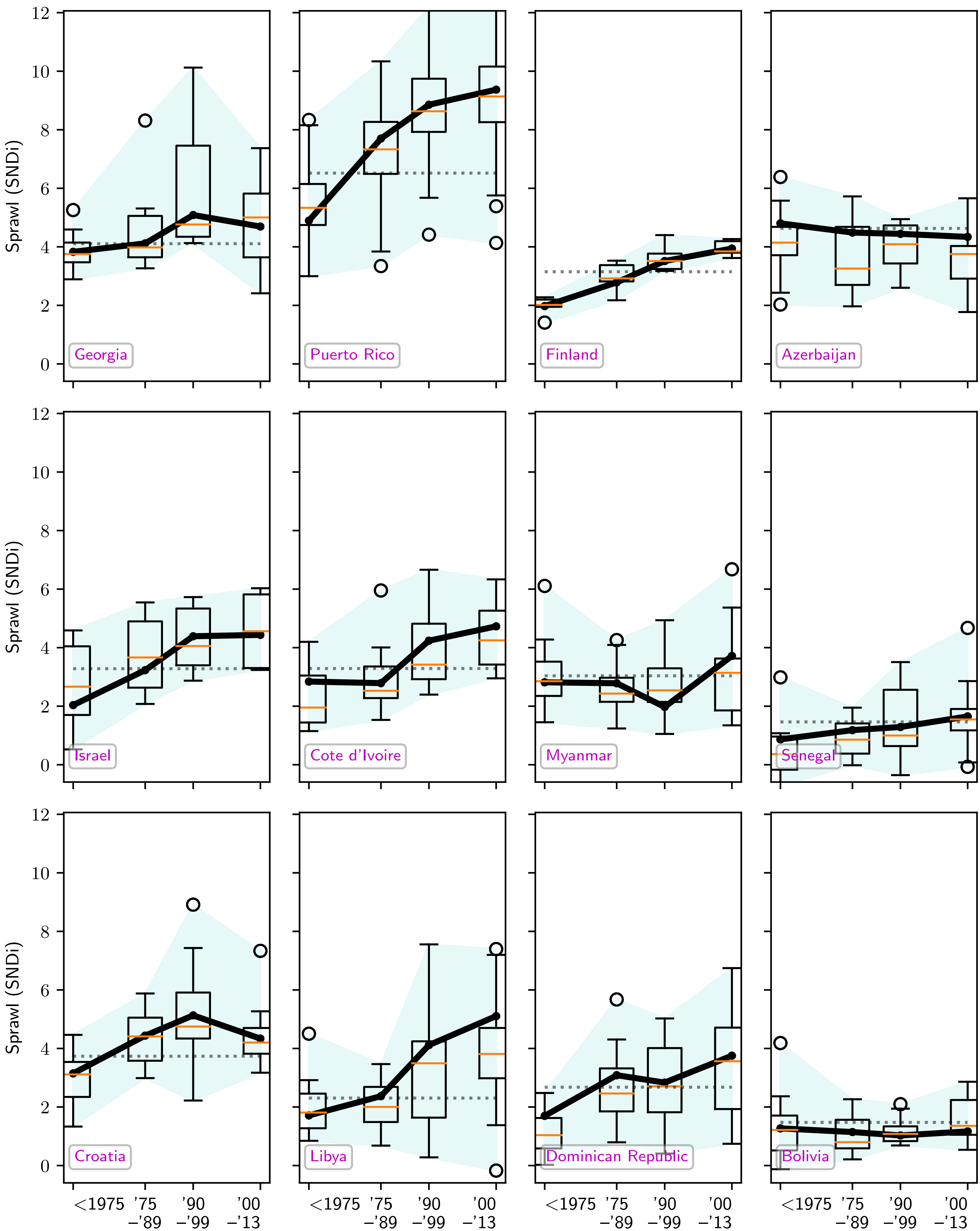
Sprawl (SNDi)
Romania
Korea, Rep.
Czech Republic
Iraq
Austria
Ecuador
Denmark
Taiwan, China
Chile
Switzerland
Hungary
Bulgaria
<1975
'75 –'89
'90 –'99
'00 –'13

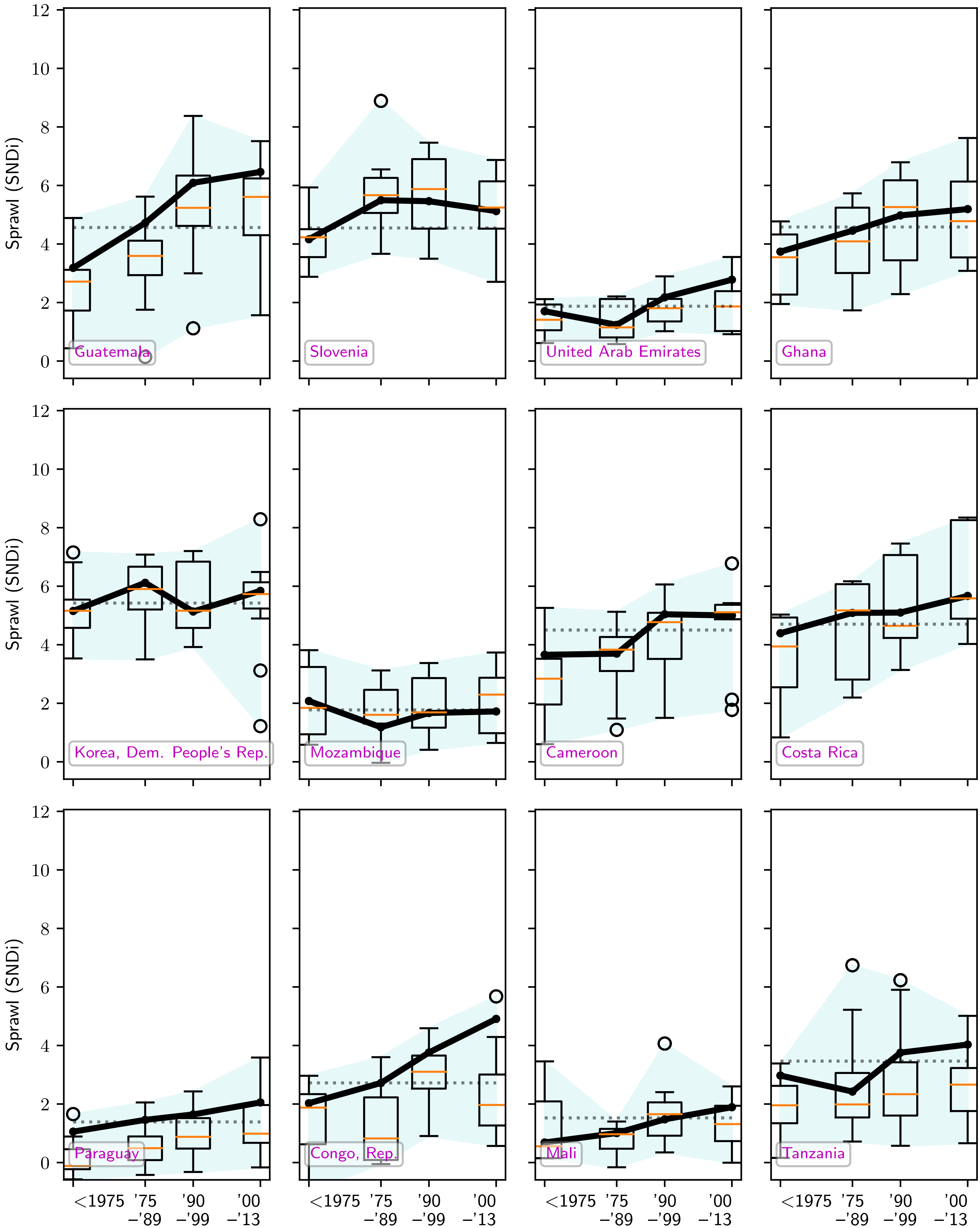


Sprawl (SNDi)
Sudan
Ethiopia
Vietnam
Morocco
Congo, Dem. Rep.
Tunisia
Uganda
Syrian Arab Republic
Uzbekistan
Sri Lanka
Pakistan
Bangladesh
<1975
'75 –'89
'90 –'99
'00 –'13

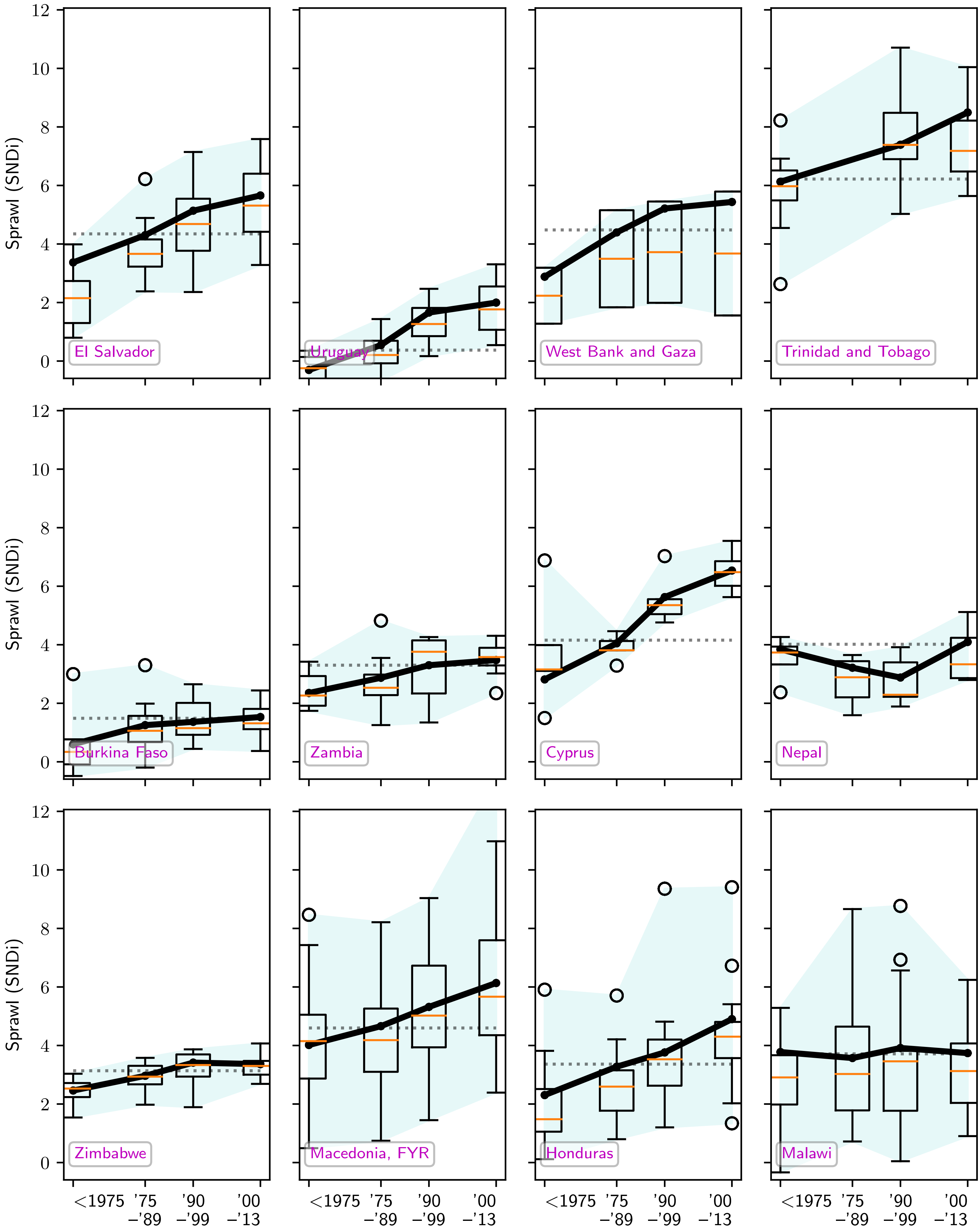


Sprawl (SNDi)
New Zealand
Belarus
Afghanistan
Kazakhstan
Norway
Cuba
Angola
Slovak Republic
Ireland
Jordan
Serbia
Moldova
<1975
'75 –'89
'90 –'99
'00 –'13

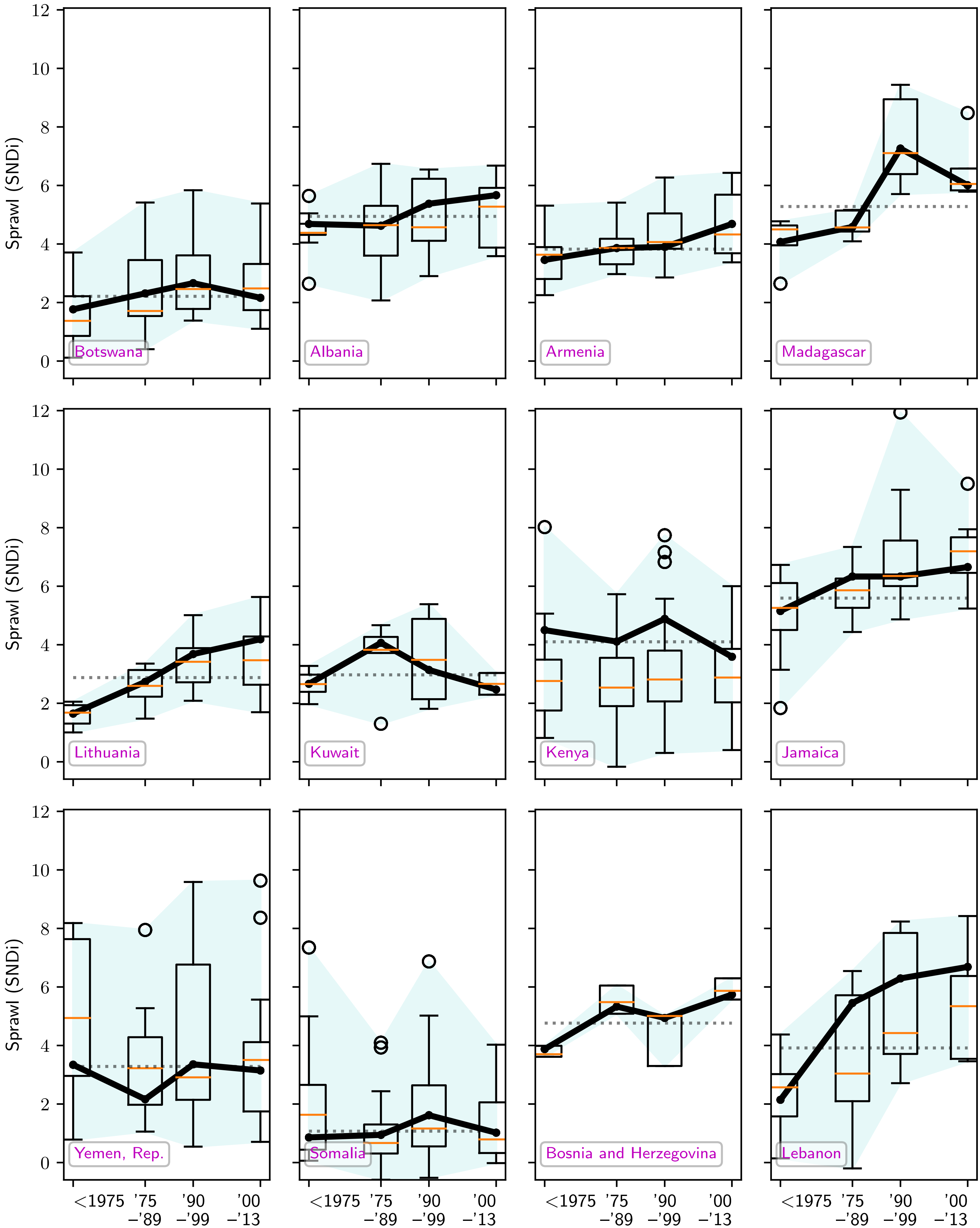

Sprawl (SNDi)
Georgia
Puerto Rico
Finland
Azerbaijan
Israel
Cote d'Ivoire
Myanmar
Senegal
Croatia
Libya
Dominican Republic
Bolivia
0
2
4
6
8
10
12
<1975
'75 –'89
'90 –'99
'00 –'13



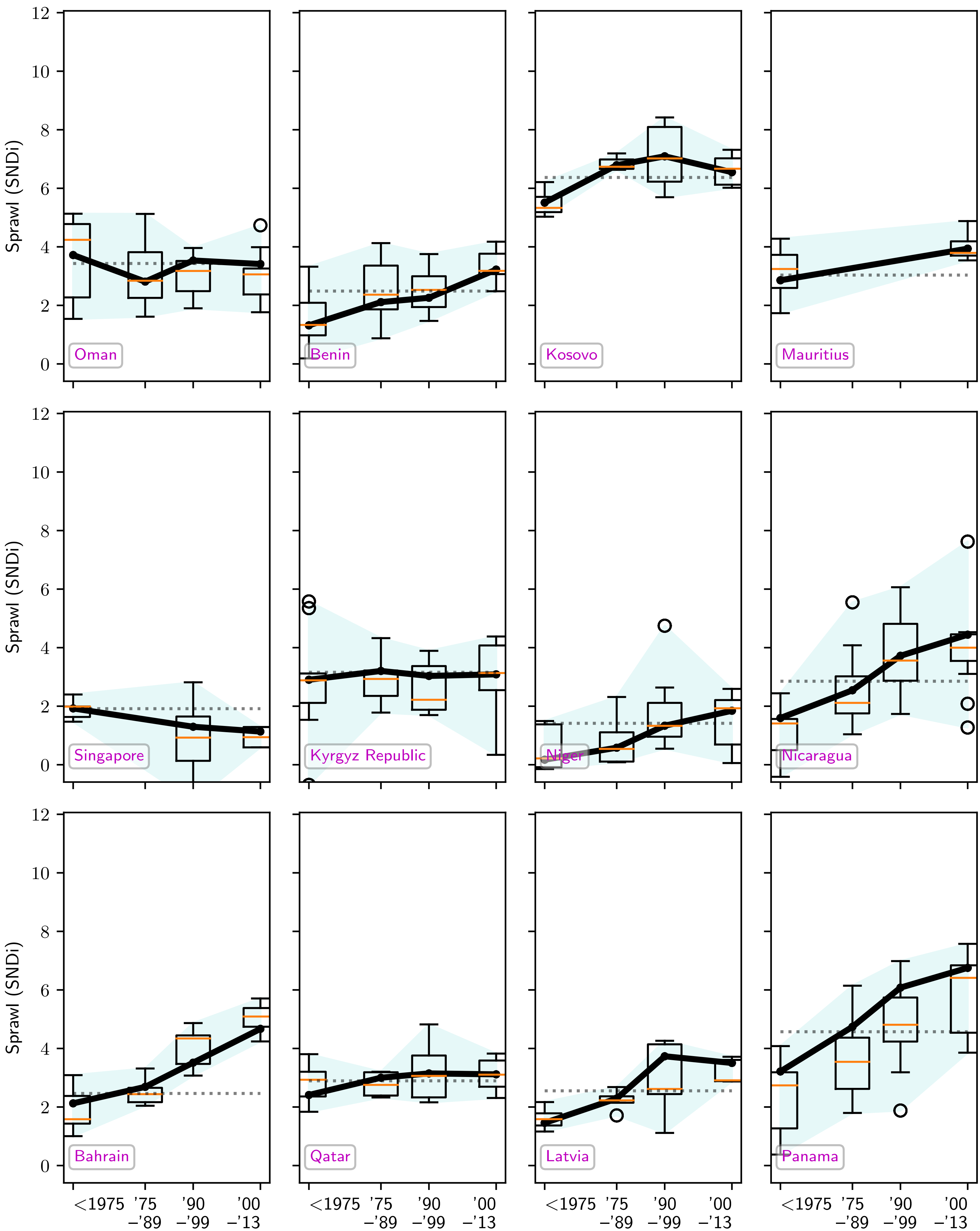
Sprawl (SNDi)
Guatemala
Slovenia
United Arab Emirates
Ghana
Korea, Dem. People's Rep.
Mozambique
Cameroon
Costa Rica
Paraguay
Congo, Rep.
Mali
Tanzania
<1975
'75 –'89
'90 –'99
'00 –'13



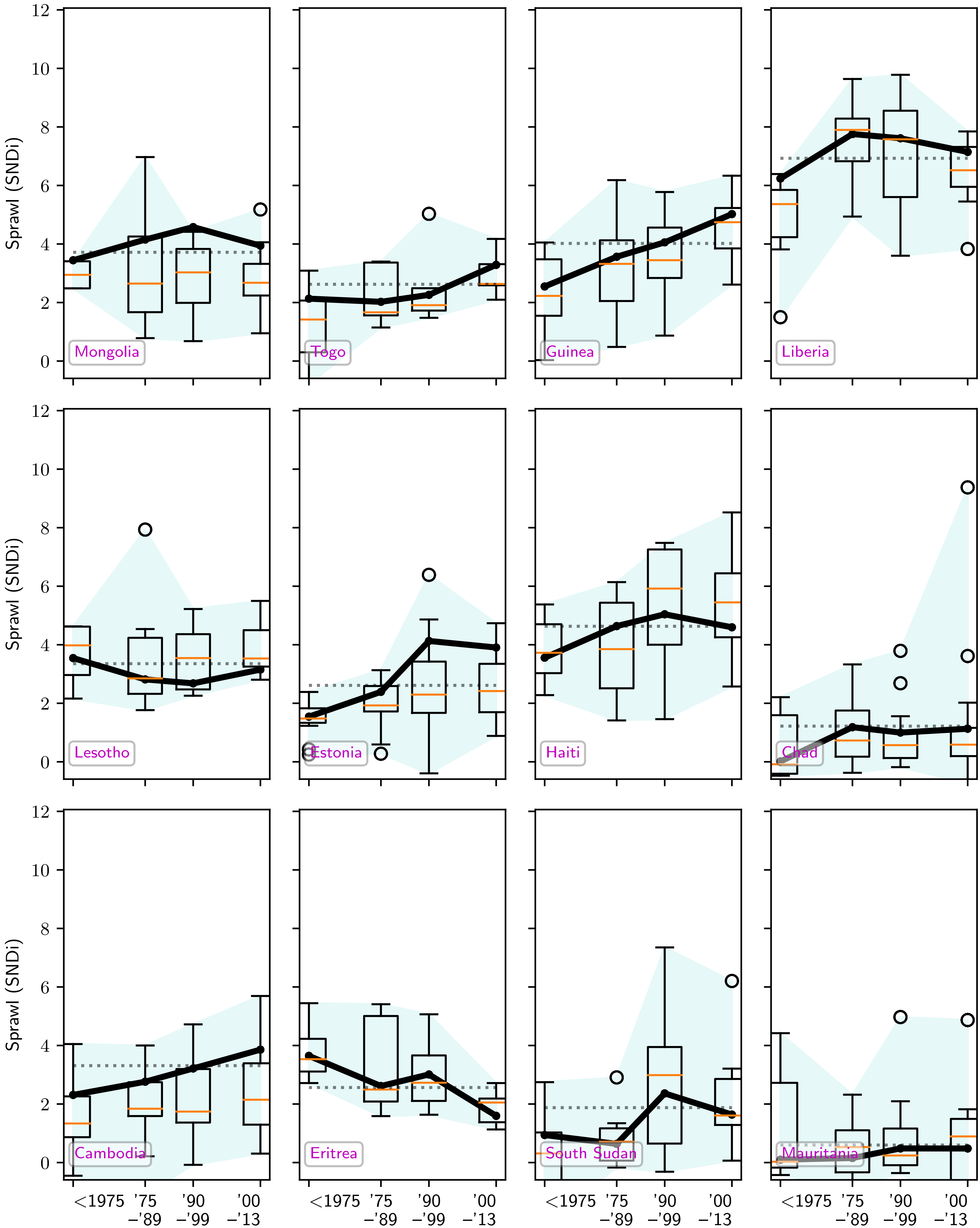
Sprawl (SNDi)
El Salvador
Uruguay
West Bank and Gaza
Trinidad and Tobago
Burkina Faso
Zambia
Cyprus
Nepal
Zimbabwe
Macedonia, FYR
Honduras
Malawi
0
2
4
6
8
10
12
<1975
'75 –'89
'90 –'99
'00 –'13



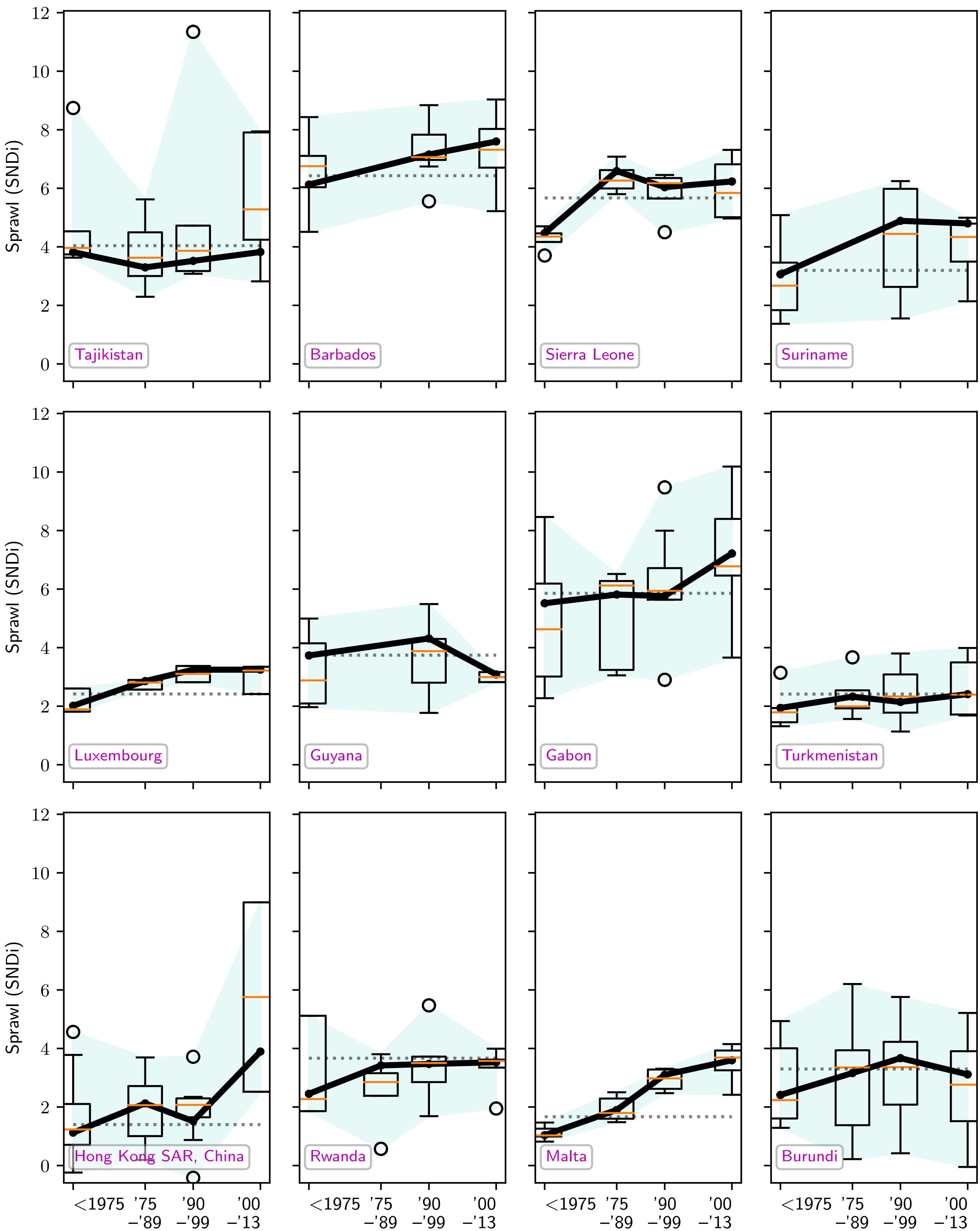
Sprawl (SNDi)
Botswana
Albania
Armenia
Madagascar
Lithuania
Kuwait
Kenya
Jamaica
Yemen, Rep.
Somalia
Bosnia and Herzegovina
Lebanon
<1975
'75 –'89
'90 –'99
'00 –'13



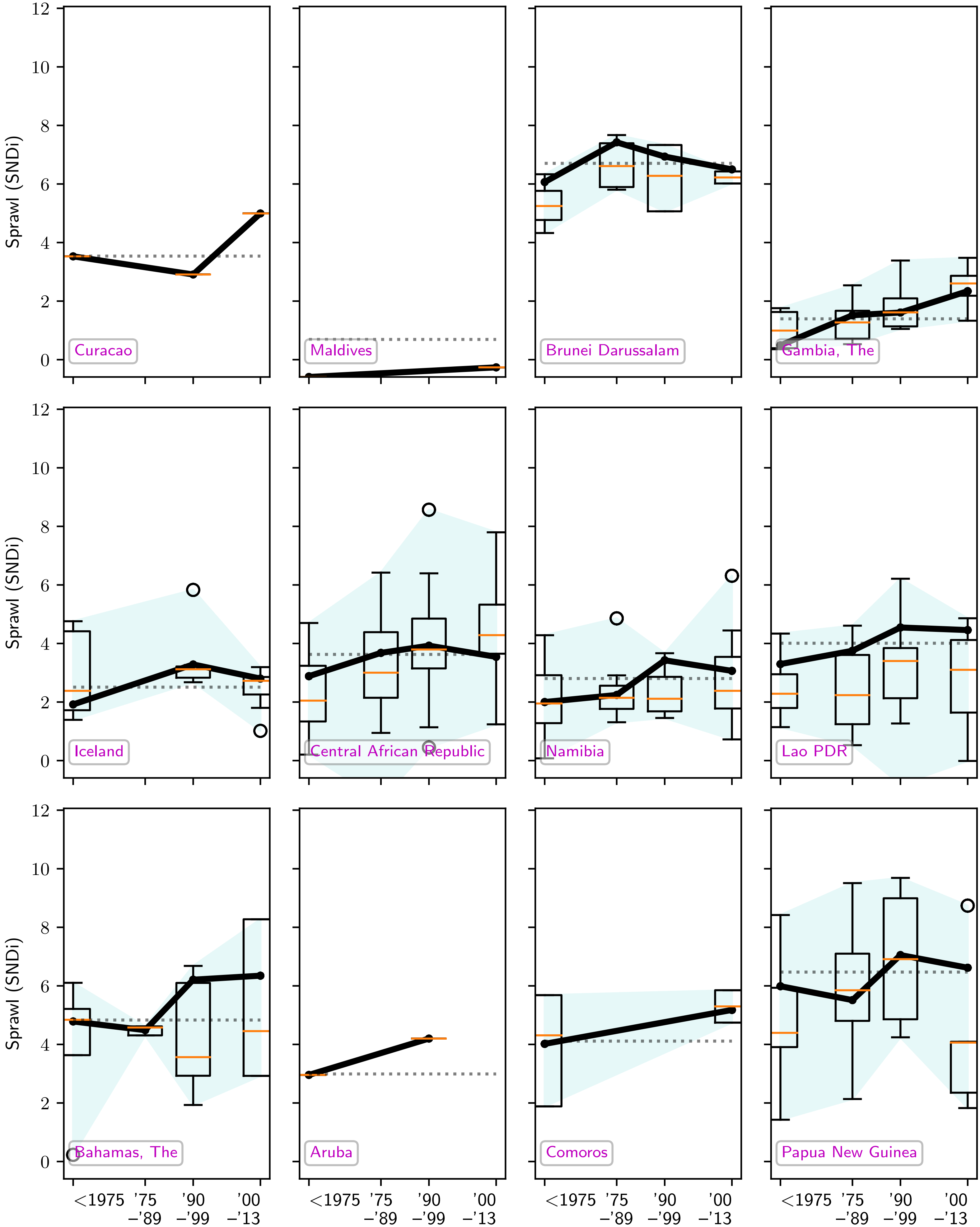
Sprawl (SNDi)
Oman
Benin
Kosovo
Mauritius
Singapore
Kyrgyz Republic
Niger
Nicaragua
Bahrain
Qatar
Latvia
Panama
<1975
'75 –'89
'90 –'99
'00 –'13
0
2
4
6
8
10
12



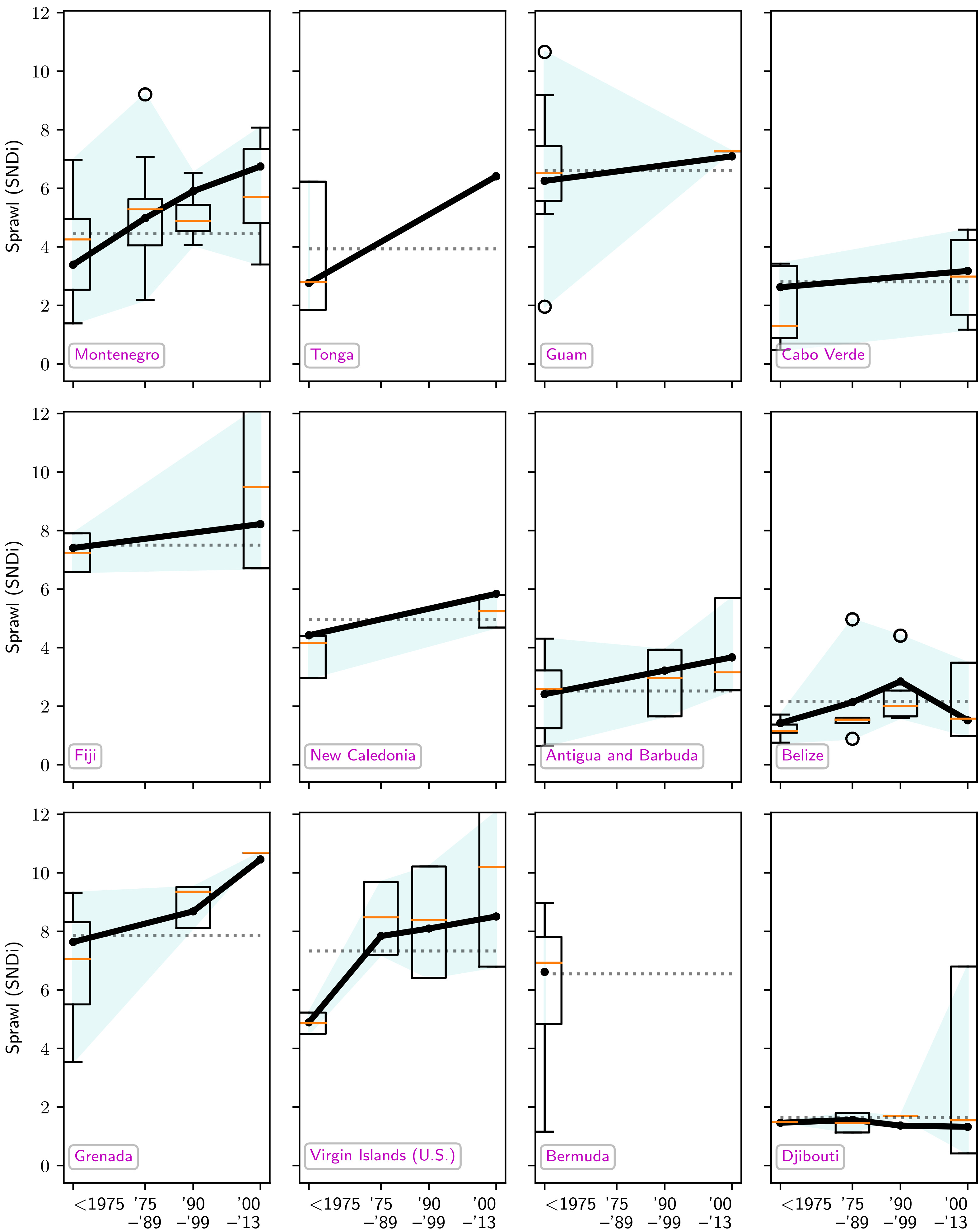
Sprawl (SNDi)
Mongolia
Togo
Guinea
Liberia
Lesotho
Estonia
Haiti
Chad
Cambodia
Eritrea
South Sudan
Mauritania
<1975
'75 –'89
'90 –'99
'00 –'13

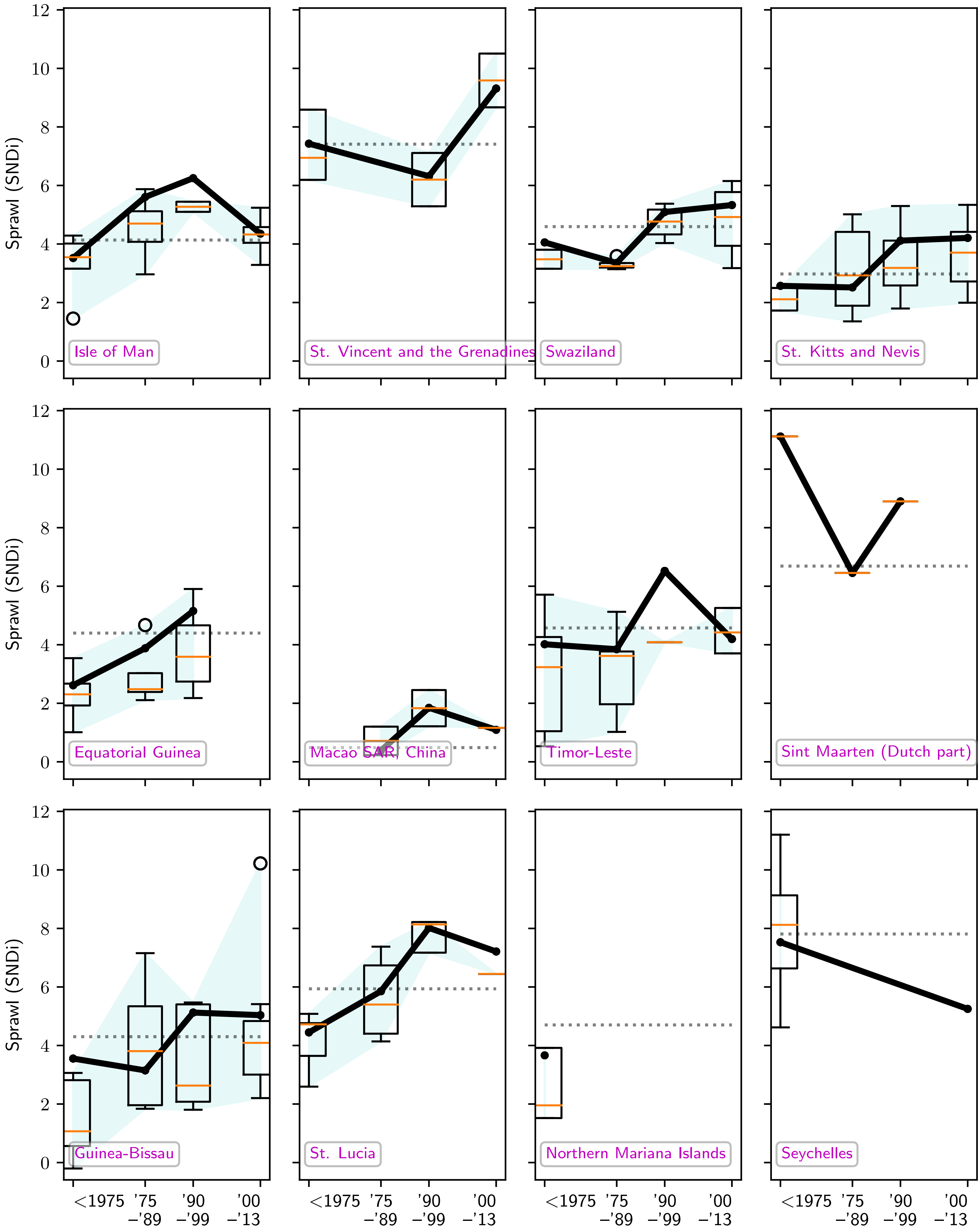


Sprawl (SNDi)
Tajikistan
Barbados
Sierra Leone
Suriname
Luxembourg
Guyana
Gabon
Turkmenistan
Hong Kong SAR, China
Rwanda
Malta
Burundi
<1975
'75 –'89
'90 –'99
'00 –'13

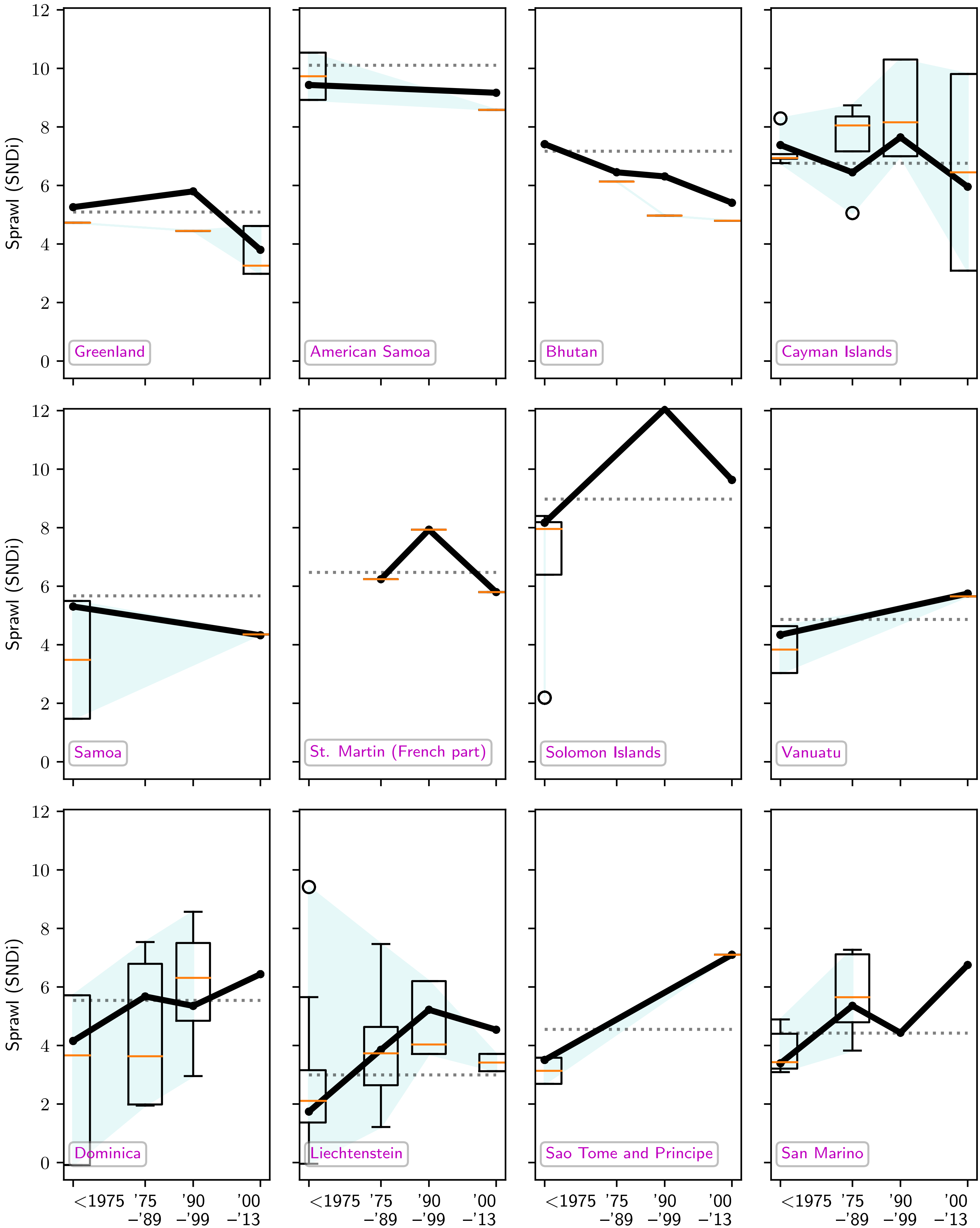


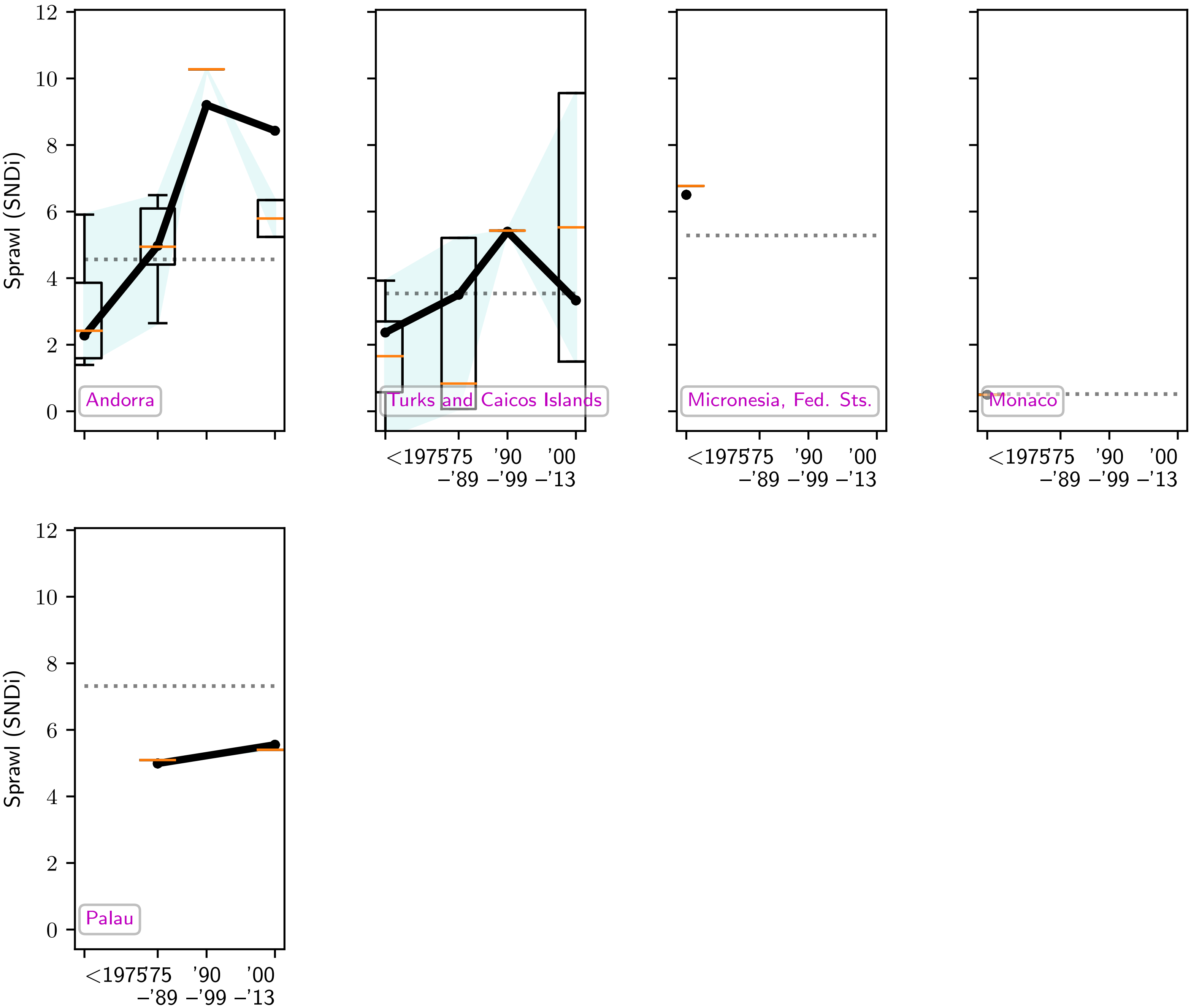
Sprawl (SNDi)
Curacao
Maldives
Brunei Darussalam
Gambia, The
Iceland
Central African Republic
Namibia
Lao PDR
Bahamas, The
Aruba
Comoros
Papua New Guinea
<1975
'75 –'89
'90 –'99
'00 –'13
0
2
4
6
8
10
12


Montenegro
Tonga
Guam
Cabo Verde
Fiji
New Caledonia
Antigua and Barbuda
Belize
Grenada
Virgin Islands (U.S.)
Bermuda
Djibouti
Sprawl (SNDi)
0
2
4
6
8
10
12
<1975
'75 –'89
'90 –'99
'00 –'13



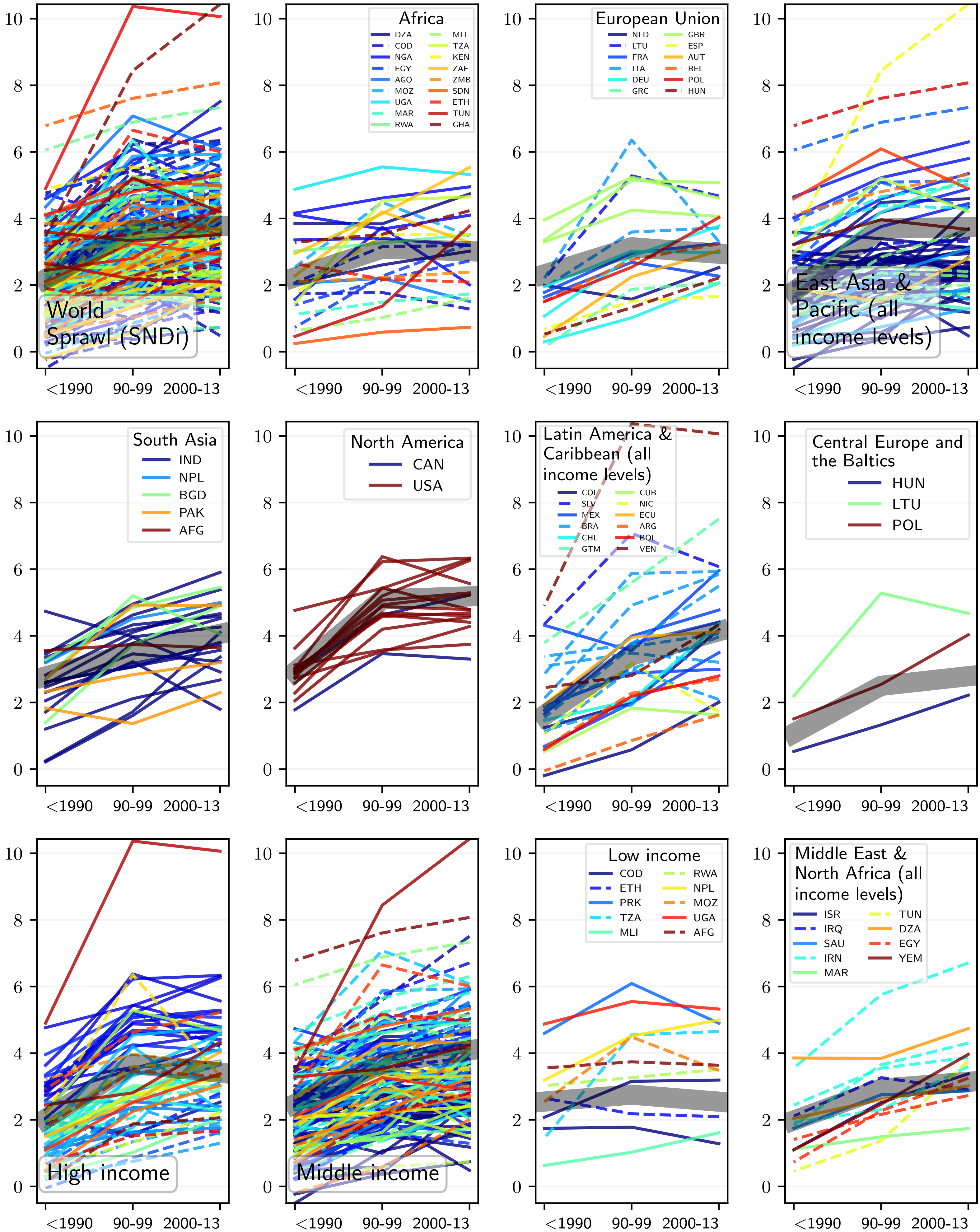
Sprawl (SNDi)
Isle of Man
St. Vincent and the Grenadines
Swaziland
St. Kitts and Nevis
Equatorial Guinea
Macao SAR, China
Timor-Leste
Sint Maarten (Dutch part)
Guinea-Bissau
St. Lucia
Northern Mariana Islands
Seychelles
<1975
'75 –'89
'90 –'99
'00 –'13

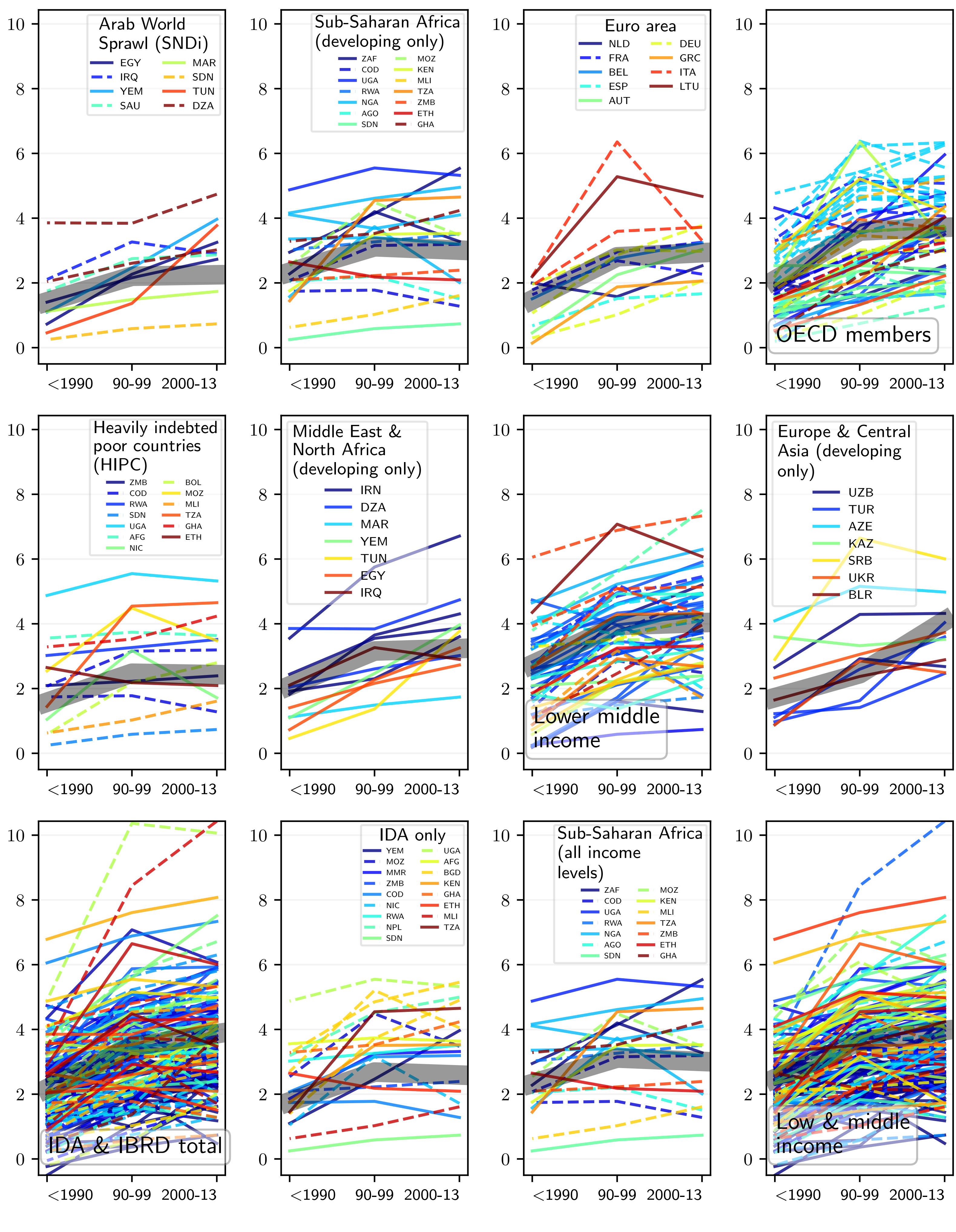

Sprawl (SNDi)
Greenland
American Samoa
Bhutan
Cayman Islands
Samoa
St. Martin (French part)
Solomon Islands
Vanuatu
Dominica
Liechtenstein
Sao Tome and Principe
San Marino
<1975
'75 –'89
'90 –'99
'00 –'13
0
2
4
6
8
10
12


Sprawl (SNDi)
0
2
4
6
8
10
12
Andorra
Turks and Caicos Islands
Micronesia, Fed. Sts.
Monaco
Palau
<1975
'75
–'89
'90
–'99
'00
–'13

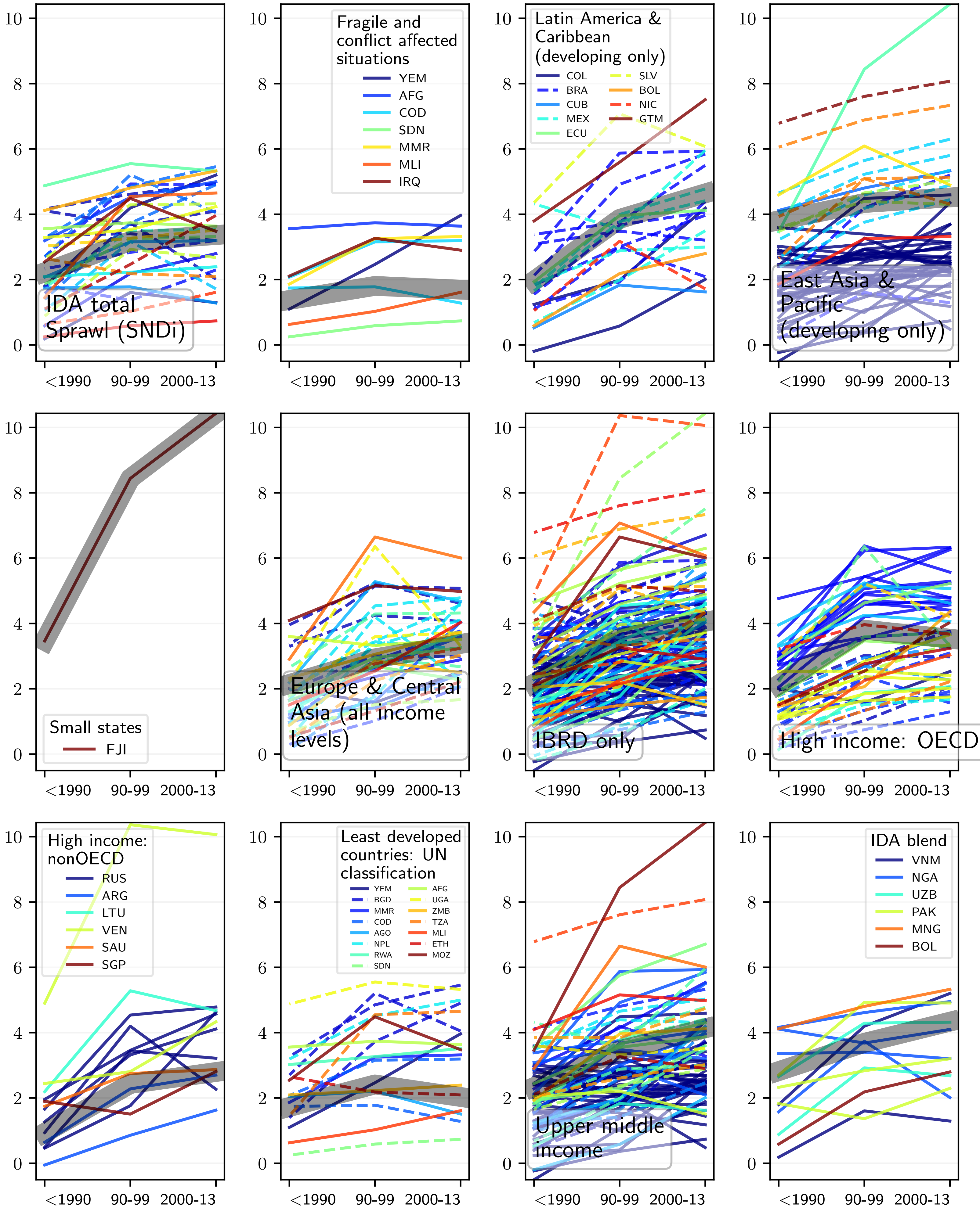
F.11 City trend plots (by region)

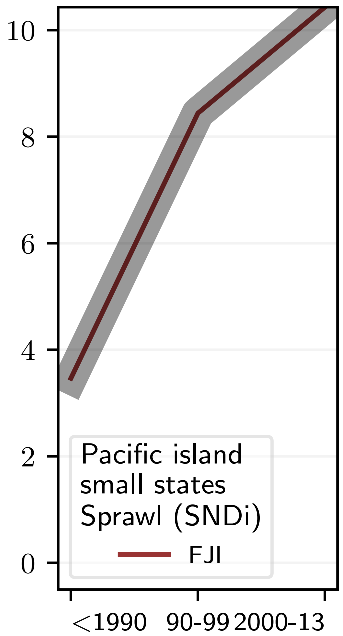
The following plots show city trends in each region. Each line represents one city; in some cases there is more than one city per country. For more detail, see the tabular data. The following pages show results only for SNDi. Other metrics are available online at:
https://alum.mit.edu/www/cpbl/publications/2020-PNAS-sprawl.


World Sprawl (SNDi)
Africa
DZA COD NGA EGY AGO MOZ UGA MAR RWA MLI TZA KEN ZAF ZMB SDN ETH TUN GHA
European Union
NLD LTU FRA ITA DEU GRC GBR ESP AUT BEL POL HUN
East Asia & Pacific (all income levels)
South Asia
IND NPL BGD PAK AFG
North America
CAN USA
Latin America & Caribbean (all income levels)
COL SLV MEX BRA CHL GTM CUB NIC ECU ARG BOL VEN
Central Europe and the Baltics
HUN LTU POL
High income
Middle income
Low income
COD ETH PRK TZA MLI RWA NPL MOZ UGA AFG
Middle East & North Africa (all income levels)
ISR IRQ SAU IRN MAR TUN DZA EGY YEM
0 2 4 6 8 10
<1990 90-99 2000-13



Arab World
Sprawl (SNDi)
EGY
IRQ
YEM
SAU
MAR
SDN
TUN
DZA
Sub-Saharan Africa
(developing only)
ZAF
COD
UGA
RWA
NGA
AGO
SDN
MOZ
KEN
MLI
TZA
ZMB
ETH
GHA
Euro area
NLD
FRA
BEL
ESP
AUT
DEU
GRC
ITA
LTU
OECD members
Heavily indebted
poor countries
(HIPC)
ZMB
COD
RWA
SDN
UGA
AFG
NIC
BOL
MOZ
MLI
TZA
GHA
ETH
Middle East &
North Africa
(developing only)
IRN
DZA
MAR
YEM
TUN
EGY
IRQ
Lower middle
income
Europe & Central
Asia (developing
only)
UZB
TUR
AZE
KAZ
SRB
UKR
BLR
IDA & IBRD total
IDA only
YEM
MOZ
MMR
ZMB
COD
NIC
RWA
NPL
SDN
UGA
AFG
BGD
KEN
GHA
ETH
MLI
TZA
Sub-Saharan Africa
(all income
levels)
ZAF
COD
UGA
RWA
NGA
AGO
SDN
MOZ
KEN
MLI
TZA
ZMB
ETH
GHA
Low & middle
income
0
2
4
6
8
10
<1990
90-99
2000-13


IDA total Sprawl (SNDi)
Fragile and conflict affected situations
YEM
AFG
COD
SDN
MMR
MLI
IRQ
Latin America & Caribbean (developing only)
COL
BRA
CUB
MEX
ECU
SLV
BOL
NIC
GTM
East Asia & Pacific (developing only)
Small states
FJI
Europe & Central Asia (all income levels)
IBRD only
High income: OECD
High income: nonOECD
RUS
ARG
LTU
VEN
SAU
SGP
Least developed countries: UN classification
YEM
BGD
MMR
COD
AGO
NPL
RWA
SDN
AFG
UGA
ZMB
TZA
MLI
ETH
MOZ
Upper middle income
IDA blend
VNM
NGA
UZB
PAK
MNG
BOL
<1990
90-99
2000-13
0
2
4
6
8
10

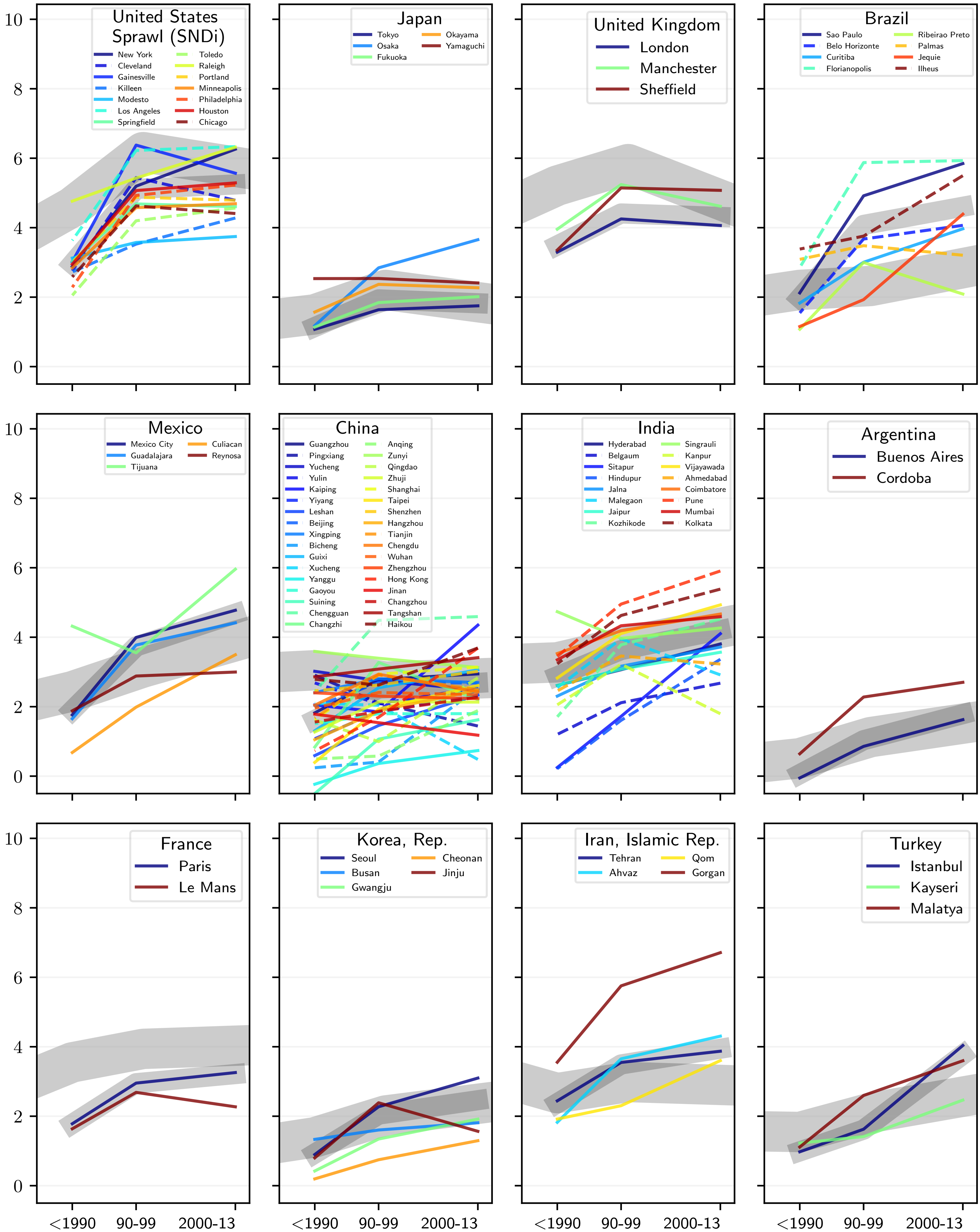


10
8
6
4
2
0
Pacific island
small states
Sprawl (SNDi)
FJI
<1990
90-99
2000-13

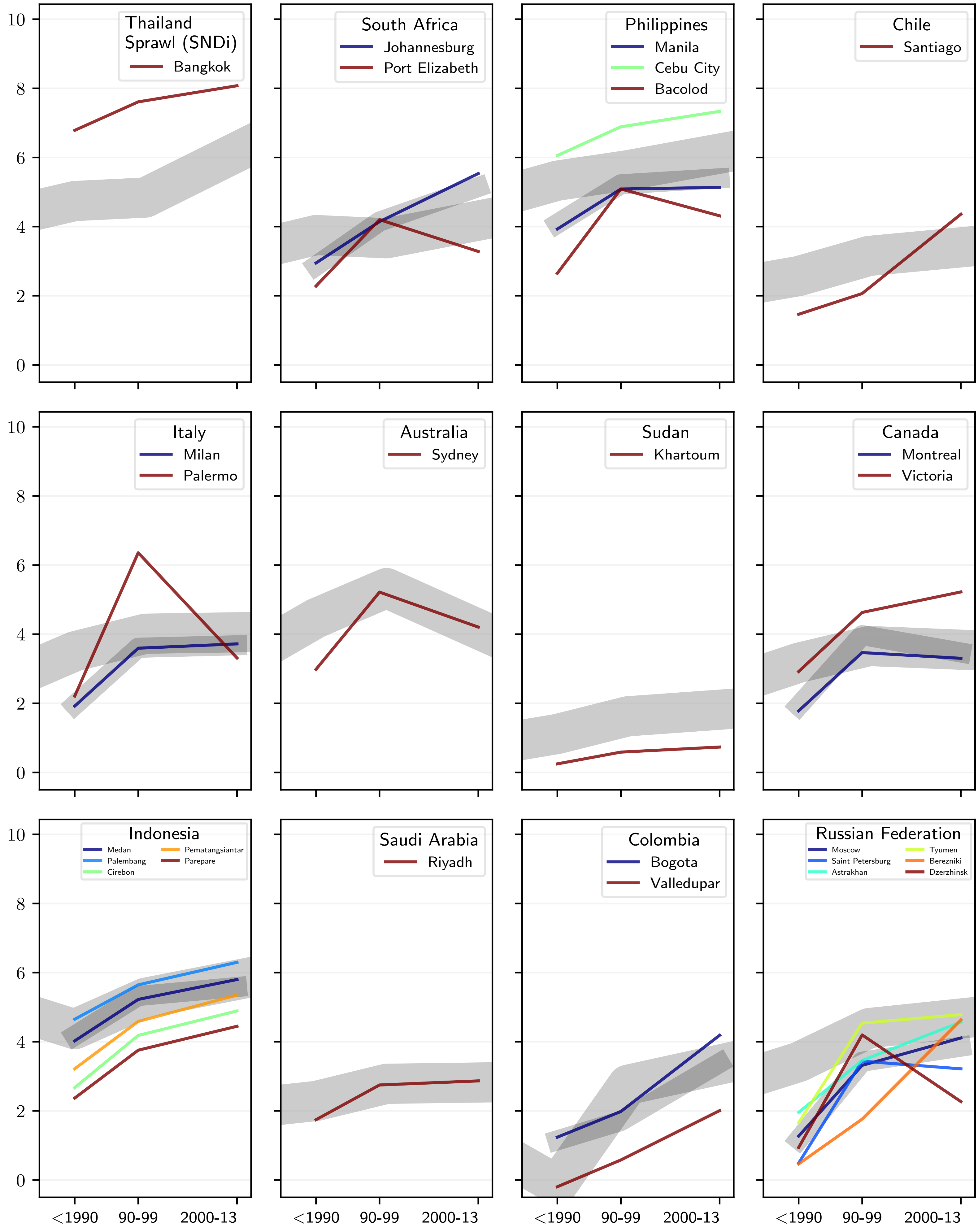
F.12 City trend plots (by country)

In the plots below, the widest gray line is centered on the trend for the entire country's urban street network, while the less wide gray line is the node-weighted average over only the cities shown (i.e., all those available in the Atlas of Urban Expansion). Quantities are exact; line width does *not* represent confidence intervals. Countries are ordered by the number of nodes in the 2018 road stock. For more detail, see the tabular data.

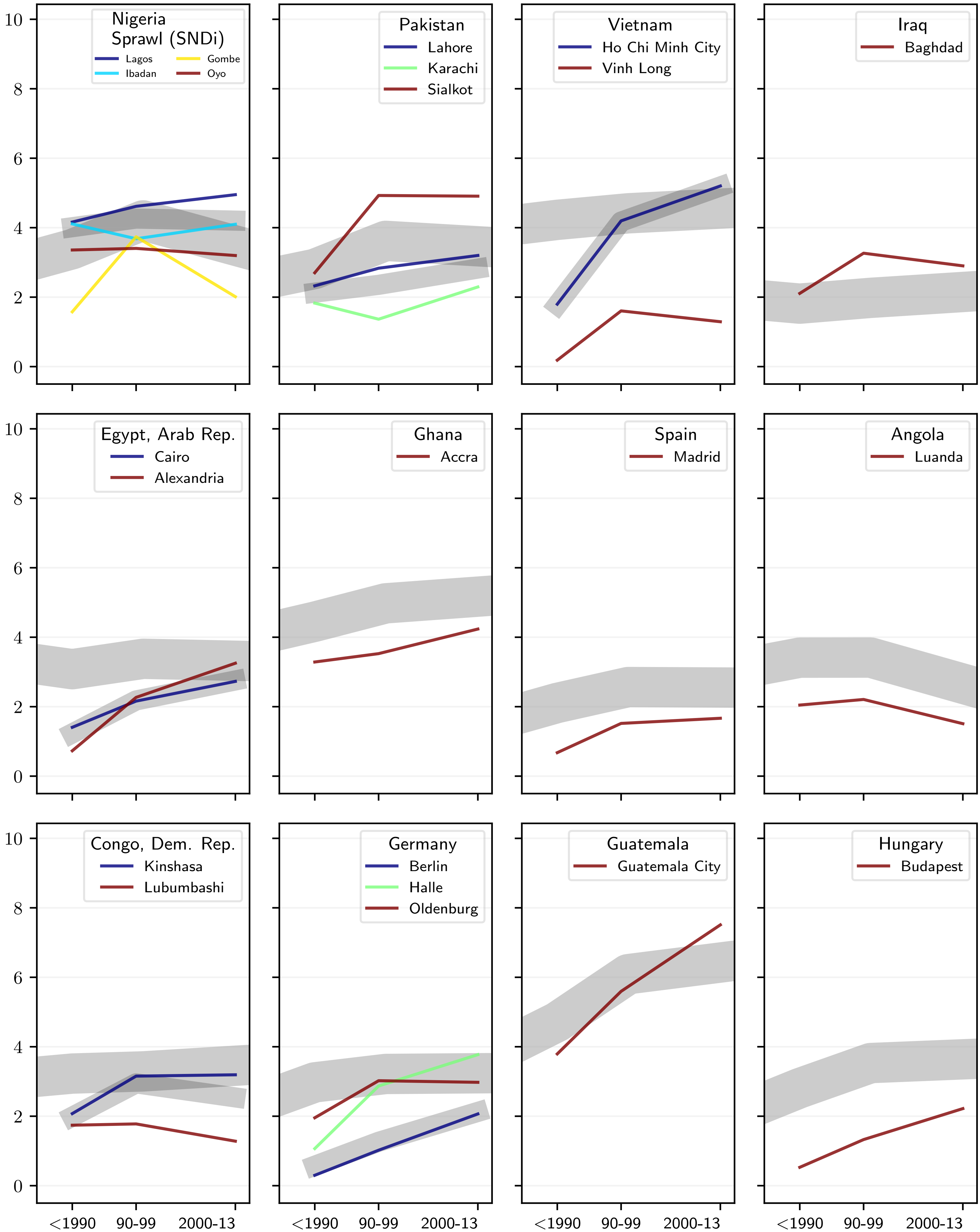
The following pages show results only for SNDi. Other metrics are available online at: https://alum.mit.edu/www/cpbl/publications/2020-PNAS-sprawl.



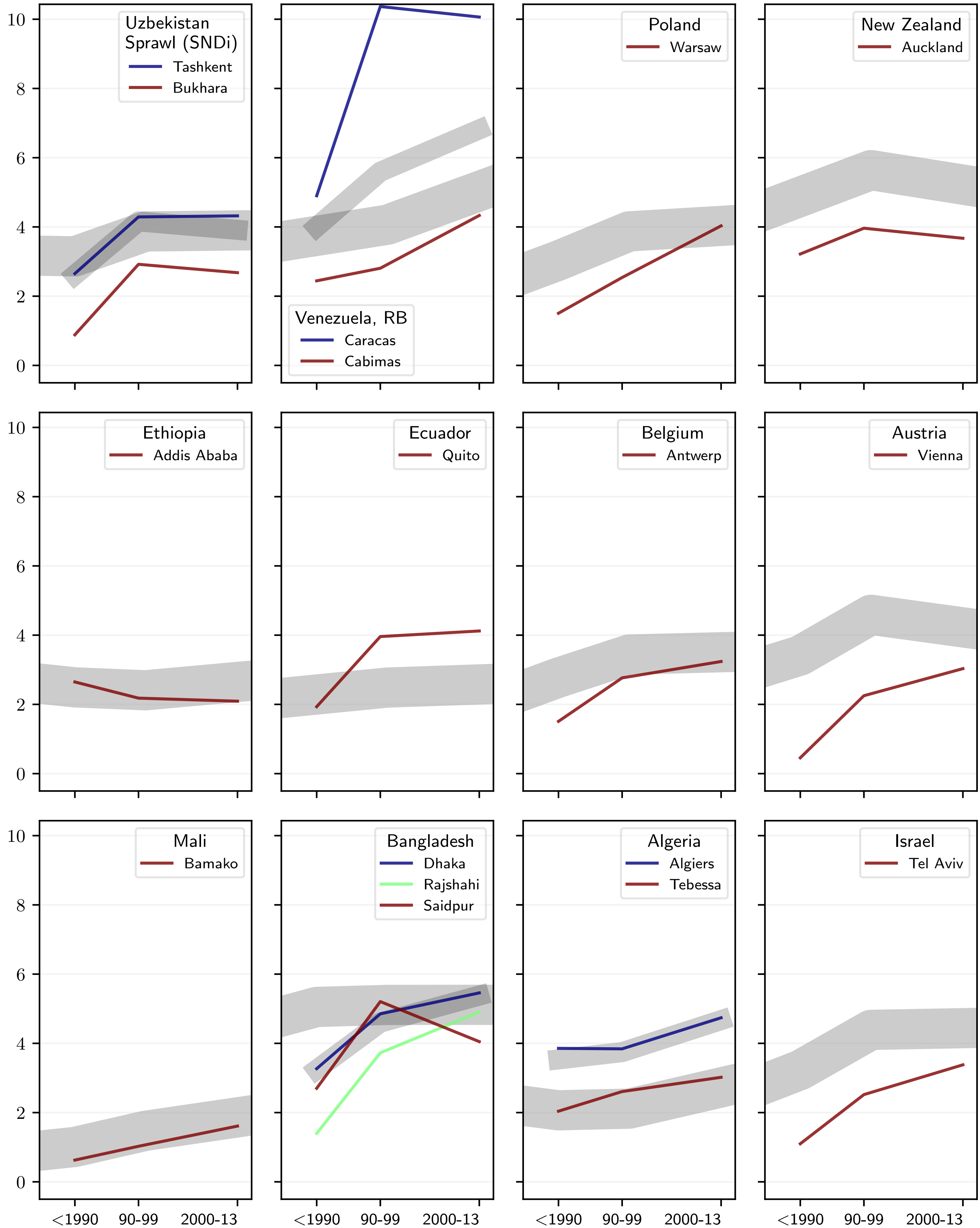
United States Sprawl (SNDi)
New York
Cleveland
Gainesville
Killeen
Modesto
Los Angeles
Springfield
Toledo
Raleigh
Portland
Minneapolis
Philadelphia
Houston
Chicago
Japan
Tokyo
Osaka
Fukuoka
Okayama
Yamaguchi
United Kingdom
London
Manchester
Sheffield
Brazil
Sao Paulo
Belo Horizonte
Curitiba
Florianopolis
Ribeirao Preto
Palmas
Jequie
Ilheus
Mexico
Mexico City
Guadalajara
Tijuana
Culiacan
Reynosa
China
Guangzhou
Pingxiang
Yucheng
Yulin
Kaiping
Yiyang
Leshan
Beijing
Xingping
Bicheng
Guixi
Xucheng
Yanggu
Gaoyou
Suining
Chengguan
Changzhi
Anqing
Zunyi
Qingdao
Zhuji
Shanghai
Taipei
Shenzhen
Hangzhou
Tianjin
Chengdu
Wuhan
Zhengzhou
Hong Kong
Jinan
Changzhou
Tangshan
Haikou
India
Hyderabad
Belgaum
Sitapur
Hindupur
Jalna
Malegaon
Jaipur
Kozhikode
Singrauli
Kanpur
Vijayawada
Ahmedabad
Coimbatore
Pune
Mumbai
Kolkata
Argentina
Buenos Aires
Cordoba
France
Paris
Le Mans
Korea, Rep.
Seoul
Busan
Gwangju
Cheonan
Jinju
Iran, Islamic Rep.
Tehran
Ahvaz
Qom
Gorgan
Turkey
Istanbul
Kayseri
Malatya
0
2
4
6
8
10
<1990
90-99
2000-13



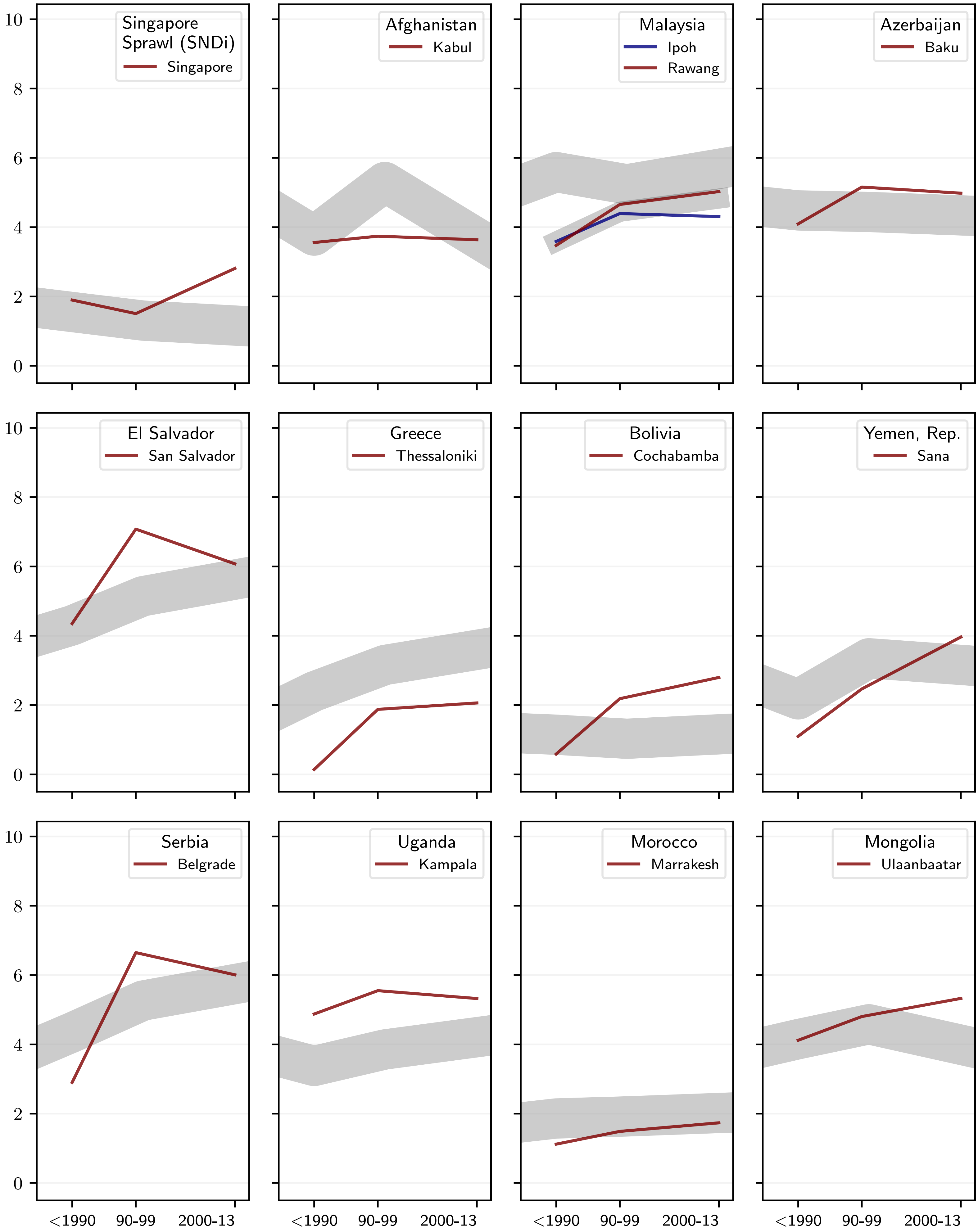
Thailand Sprawl (SNDi)
Bangkok
South Africa
Johannesburg
Port Elizabeth
Philippines
Manila
Cebu City
Bacolod
Chile
Santiago
Italy
Milan
Palermo
Australia
Sydney
Sudan
Khartoum
Canada
Montreal
Victoria
Indonesia
Medan
Palembang
Cirebon
Pematangsiantar
Parepare
Saudi Arabia
Riyadh
Colombia
Bogota
Valledupar
Russian Federation
Moscow
Saint Petersburg
Astrakhan
Tyumen
Berezniki
Dzerzhinsk
0
2
4
6
8
10
<1990
90-99
2000-13



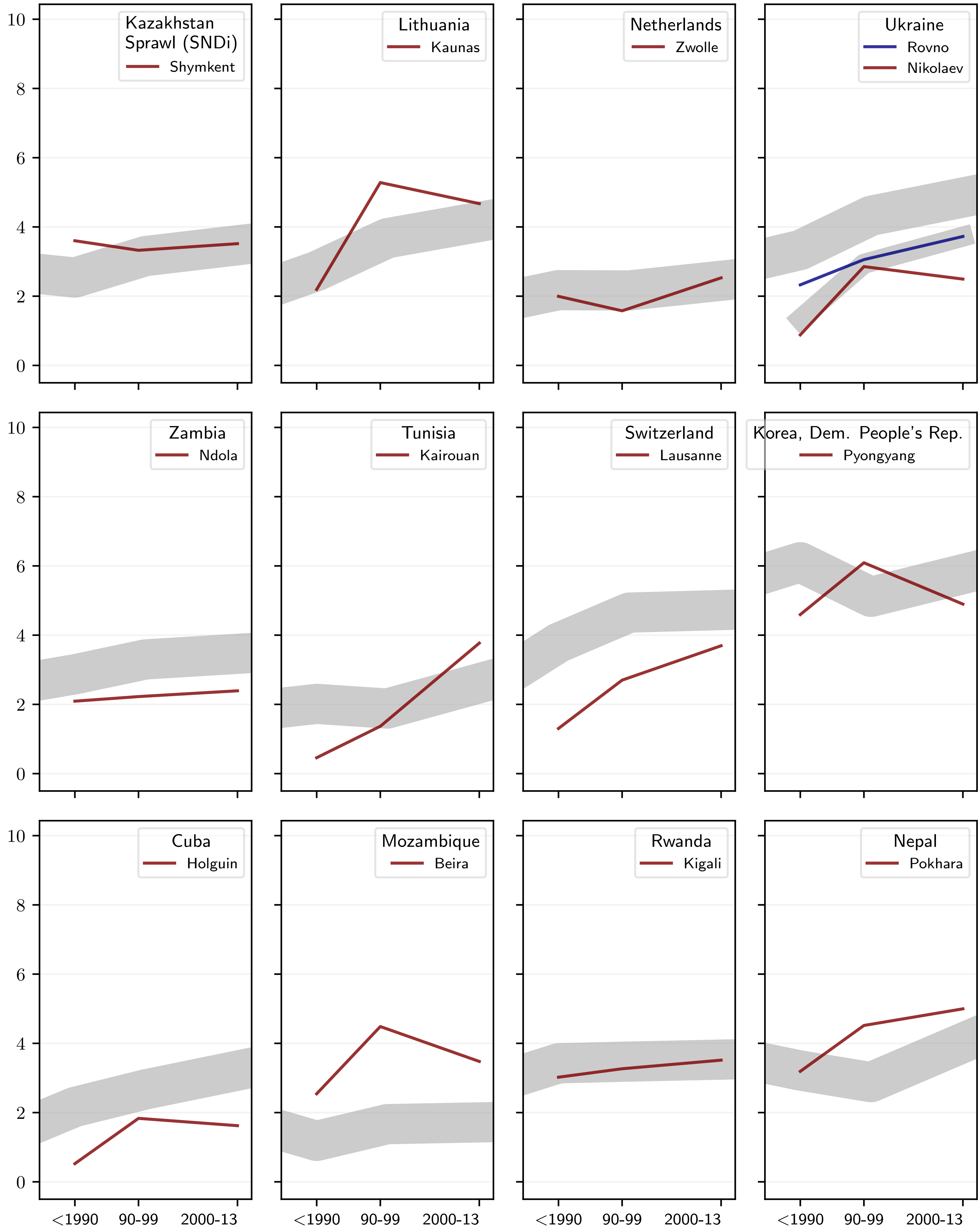
Nigeria
Sprawl (SNDi)
Lagos
Ibadan
Gombe
Oyo
Pakistan
Lahore
Karachi
Sialkot
Vietnam
Ho Chi Minh City
Vinh Long
Iraq
Baghdad
Egypt, Arab Rep.
Cairo
Alexandria
Ghana
Accra
Spain
Madrid
Angola
Luanda
Congo, Dem. Rep.
Kinshasa
Lubumbashi
Germany
Berlin
Halle
Oldenburg
Guatemala
Guatemala City
Hungary
Budapest
0
2
4
6
8
10
<1990
90-99
2000-13



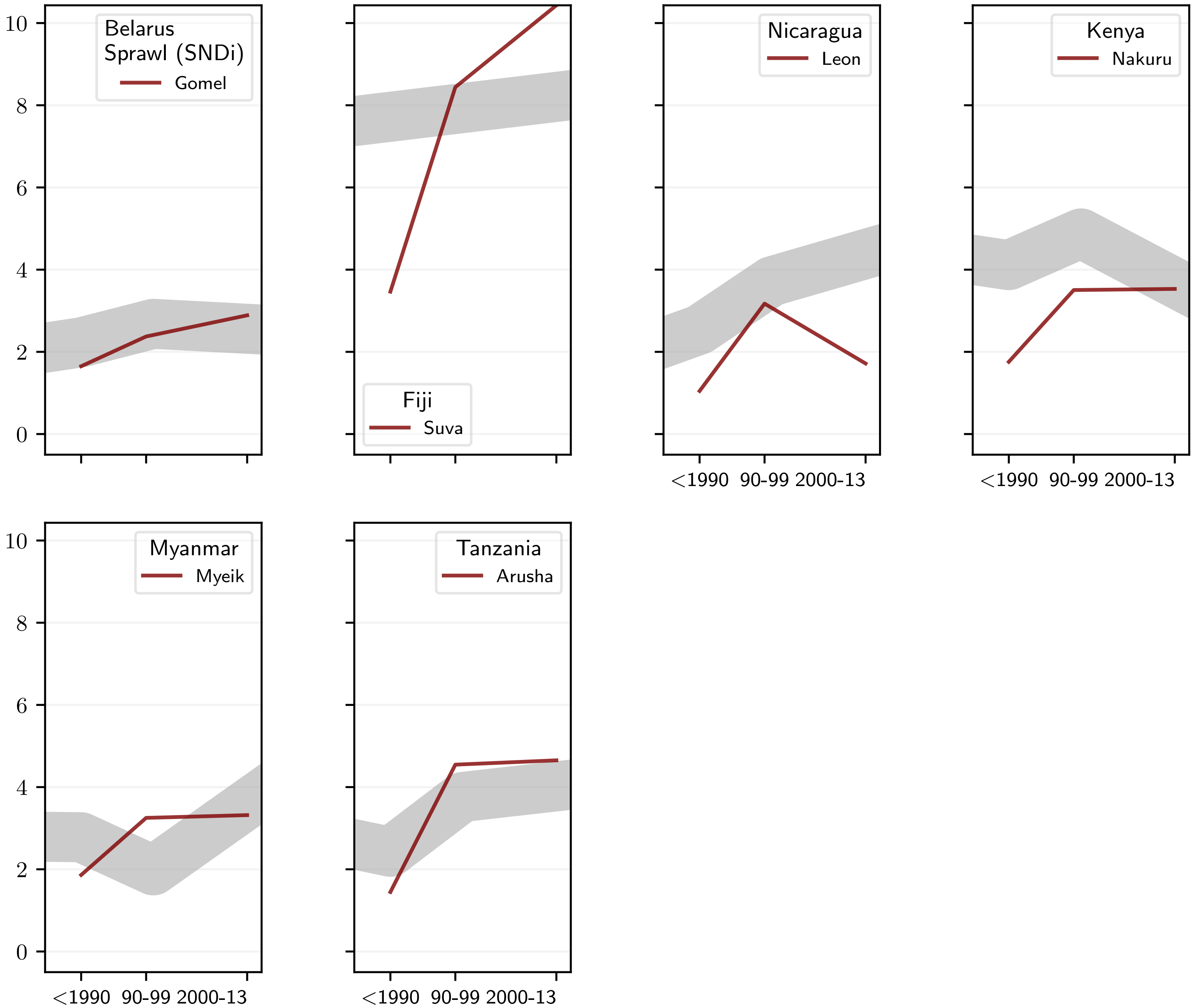
Uzbekistan
Sprawl (SNDi)
Tashkent
Bukhara
Venezuela, RB
Caracas
Cabimas
Poland
Warsaw
New Zealand
Auckland
Ethiopia
Addis Ababa
Ecuador
Quito
Belgium
Antwerp
Austria
Vienna
Mali
Bamako
Bangladesh
Dhaka
Rajshahi
Saidpur
Algeria
Algiers
Tebessa
Israel
Tel Aviv
0
2
4
6
8
10
<1990
90-99
2000-13



Singapore Sprawl (SNDi)
Singapore
Afghanistan
Kabul
Malaysia
Ipoh
Rawang
Azerbaijan
Baku
El Salvador
San Salvador
Greece
Thessaloniki
Bolivia
Cochabamba
Yemen, Rep.
Sana
Serbia
Belgrade
Uganda
Kampala
Morocco
Marrakesh
Mongolia
Ulaanbaatar
0
2
4
6
8
10
<1990
90-99
2000-13



Kazakhstan
Sprawl (SNDi)
Shymkent
Lithuania
Kaunas
Netherlands
Zwolle
Ukraine
Rovno
Nikolaev
Zambia
Ndola
Tunisia
Kairouan
Switzerland
Lausanne
Korea, Dem. People's Rep.
Pyongyang
Cuba
Holguin
Mozambique
Beira
Rwanda
Kigali
Nepal
Pokhara
0
2
4
6
8
10
<1990
90-99
2000-13



Belarus
Sprawl (SNDi)
Gomel
Fiji
Suva
Nicaragua
Leon
Kenya
Nakuru
Myanmar
Myeik
Tanzania
Arusha
0
2
4
6
8
10
<1990
90-99
2000-13