Disentangling the Impact of Infrastructure on Trade Using a New Index of Infrastructure

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joint work with Julian Donaubauer, Alexander Glas and Peter Nunnenkamp

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Motivation and Literature

- "In the trade literature, the role of infrastructure remains largely unexplored" Bougheas et al. (1999 JIE)
- Recent literature:
  - ⇒ More and better infrastructure reduces trade-related transaction costs (e.g., Limão and Venables, 2001 WBER; Vijil and Wagner, 2012; Portugal-Perez and Wilson, 2012 WD; Francois and Manchin, 2013 WD)
  - ⇒ Positive effects of infrastructure on international trade relations

Motivation and Literature

- Literature on the role of infrastructure for international trade is still subject to several limitations.
- lack of understanding how and to which extend infrastructure actually reduce the cost of trading and how the resulting trade cost reductions affect welfare

$\Rightarrow$ Railroads of the Raj: railroads decrease trade costs and interregional price gaps, increased interregional and international trade, increased real income levels (Donaldson, forthcoming AER)

- We assess the relation between infrastructure and international trade by using a measure for quantity and quality of infrastructure and try to disentangle the channels through which infrastructure impacts trade

Gravity and Infrastructure

- structural gravity framework (Anderson and Van Wincoop, 2003):

$$X_{ij} = \frac{Y_i E_j}{Y^W} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \tag{1}$$

where
- X_{ij} exports from i to j
- Y_i exporter is production of traded goods
- E_j importer j's expenditures for consumption
- t_{ij} iceberg-type transport cost
- Π_i and P_j outward and inward multilateral resistance terms

$$\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j} \right)^{1-\sigma} \frac{E_j}{Y^W} \tag{2}$$

$$P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i} \right)^{1-\sigma} \frac{Y_i}{Y^W} \tag{3}$$

Infrastructure channels

- size component $\frac{Y_i E_j}{Y^W}$
  - $\Rightarrow$ improvement of the overall economic outlook

- trade cost term $\frac{t_{ij}}{\Pi_i P_j}$:
  - bilateral trade costs t_{ij} are a function of intranational and international trade costs $t_{ij} = f(\tau_{ii}, \tau_{jj}, \tau_{ij})$
  - $\Rightarrow$ changes in the way trade is performed
  - any improvement in infrastructure will also result in additional partial effects fo trade with other countries Π_i and P_j
  - $\Rightarrow$ average portion of trade costs borne by the exporter (importer) to (from) all its trading partners as well affected
  - $\Rightarrow$ impact on supply capacity and market access

Empirical Approach

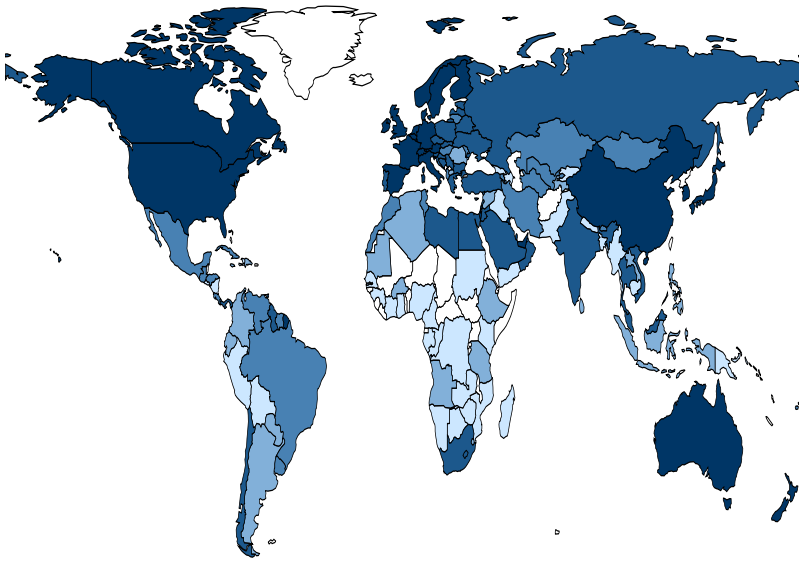
- Gravity model for bilateral trade between exporter $i = 1, ..., I$ and importer $j = 1, ..., J$ in period $t = 1992, ...2011$:

$$X_{ijs} = exp(\mathbf{T}'_{ij,s-1}\beta + \mathbf{C}'_{i,s-1}\gamma_1 + \mathbf{C}'_{j,s-1}\gamma_2 + \delta_i infra_{i,s-1} + \delta_j infra_{j,s-1} + \delta_{ij} GL\_infra_{ij,s-1} + \mu_{ij}) + \lambda_s + \epsilon_{ijs}$$

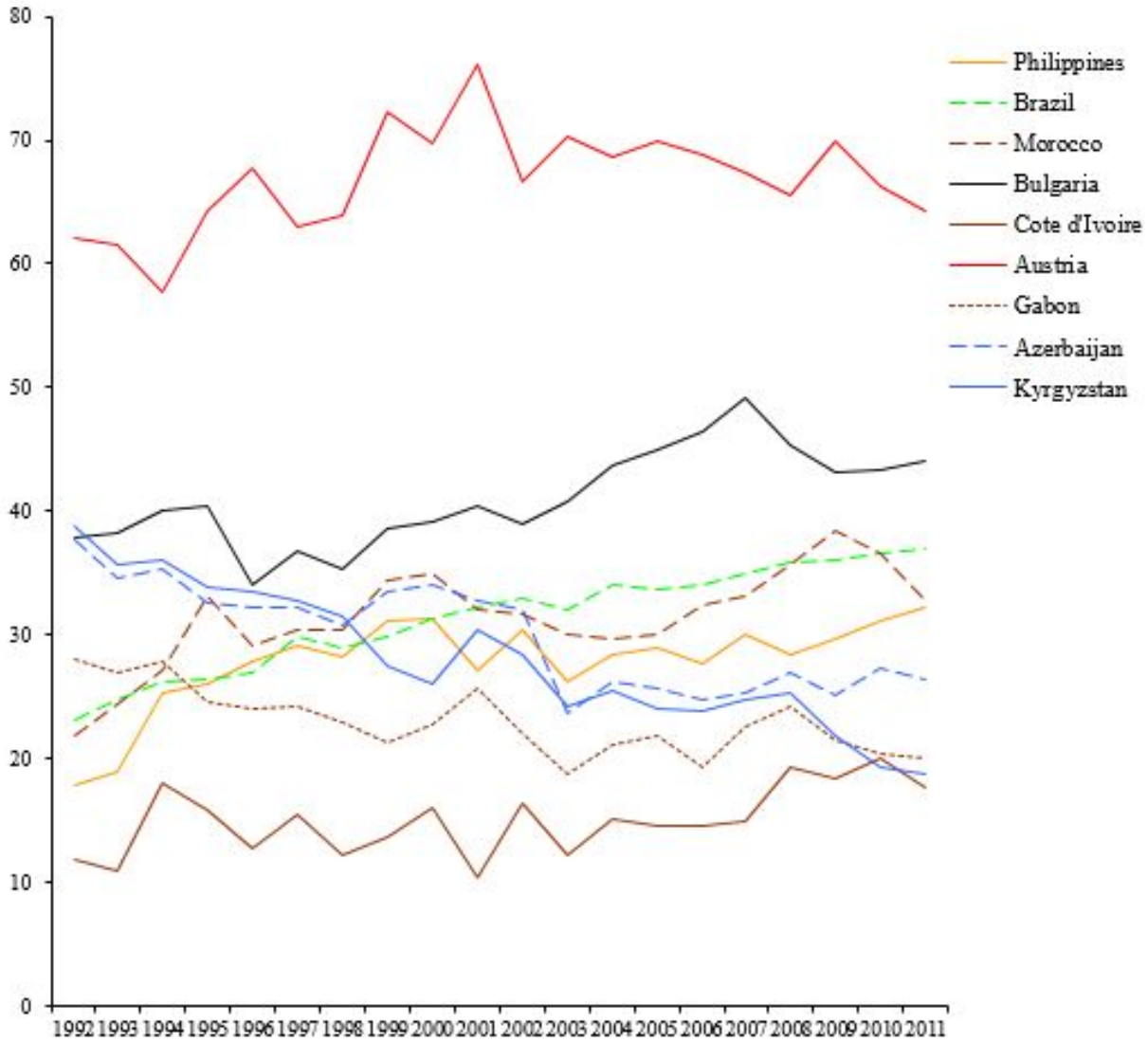
where	$X_{ij,s}$	exports	IMF DOTS
	$\mathbf{T}_{ij,s}$	time-varying trade cost vector:	
		fta, cu	Larch (2008)
		time-varying distances	Hinz(2017)
	$\mathbf{C}_{i,s}$	country specific variables:	
		GDP p.c., Population	WDI
	$infra_{i,s}$	index of infrastructure	Donaubauer et al (2016)
	$GL\_infra_{ij,s}$	(dis-)similarities in infrastructure	acc. Grubel & Lloyd (1975)

Global Index of Infrastructure

- available for a large sample of developed and developing countries (up to 165 countries)
- based on a broad dataset of 30 indicators of quantity and quality of infrastructure ▸ Indicators
- unobserved component model ▸ UCM
- 1992-2011 period
- sub-indices for specific infrastructure components: ▸ Maps
  - transport ▸ Maps
  - ICT ▸ Maps
  - energy ▸ Maps
  - finance ▸ Maps



Infrastructure Change - Examples



Infrastructure (Dis-) Similarity

- bilateral component which captures similarities in infrastructure endowment and quality
- adopting the principles of the Grubel Lloyd index:

$$GLinfra_{ij} = \frac{|infra_i - infra_j|}{infra_i + infra_j} * 100$$

Empirical Approach

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where	$X_{ij,s}$	exports	IMF DOTS
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		time-varying distances	Hinz(2017)
	$\mathbf{C}_{i,s}$	country specific variables:	
		GDP p.c., Population	WDI
	$infra_{i,s}$	index of infrastructure	Donaubauer et al (2016)
	$GL\_infra_{ij,s}$	(dis-)similarities in infrastructure	principles of Grubel & Lloyd (1975)

Baseline estimation

	(1)	(2)	(3) Baseline model	(4)
$gdppc_{i,s-1}$	0.93***	0.87***	0.87***	0.81***
	(0.13)	(0.14)	(0.13)	(0.14)
$gdppc_{j,s-1}$	0.73***	0.66***	0.66***	0.59***
	(0.15)	(0.16)	(0.15)	(0.16)
$pop_{i,s-1}$	1.22***	1.18***	1.17***	1.00***
	(0.18)	(0.19)	(0.19)	(0.26)
$pop_{j,s-1}$	0.88***	0.81***	0.80***	0.97***
	(0.20)	(0.21)	(0.21)	(0.27)
$dist_{ij,s-1}^{hinz}$	-0.24	-0.34	-0.29	-0.38
	(0.28)	(0.34)	(0.34)	(0.39)
$rta_{ij,s-1}$	0.33***	0.30***	0.28***	0.20***
	(0.06)	(0.05)	(0.05)	(0.05)
$cu_{ij,s-1}$	0.64***	0.62***	0.61***	0.60***
	(0.05)	(0.05)	(0.05)	(0.04)
$infra_{i,s-1}$		0.23**	0.16*	0.23*
		(0.09)	(0.09)	(0.12)
$infra_{j,s-1}$		0.25**	0.26***	0.46***
		(0.10)	(0.10)	(0.12)
$GL\ infra_{ij,s-1}$			0.67***	0.60***
			(0.13)	(0.15)
$tariffs_{i,s-1}$				-0.01
				(0.01)
$tariffs_{j,s-1}$				0.02
				(0.01)
$rol_{i,s-1}$				0.03
				(0.08)
$rol_{j,s-1}$				0.01
				(0.09)
No. of observations	351,991	291,703	291,703	119,768
Pair-fixed effects	yes	yes	yes	yes
Country-fixed effects	no	no	no	no
Time-fixed effects	yes	yes	yes	yes

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	(0.18)	(0.19)	(0.19)	(0.26)
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Time-fixed effects	yes	yes	yes	yes

Disentangling Infrastructure

- decomposition into direct and indirect effects
- two-step approach proposed by Head and Mayer (2014) to account for unilateral policies within the structural gravity model
- first step (high-dimensional PPML):

$$X_{ij,s} = exp(\mathbf{T}'_{ij,s-1}\beta + \delta_{ij} GL\_infra_{ij,s-1} + \eta_{i,s} + \theta_{j,s} + \mu_{ij}) + \epsilon_{ij,s}$$

where $\eta_{i,s}/\theta_{j,s}$ are exporter/importer-time FE accounting for outward/inward MLR

- second step:

$$ln(\hat{\eta_{is}}) = \alpha_0 + \bar{\beta}\bar{\mathbf{T}}'_{i,s-1} + \mathbf{C}'_{i,s-1}\gamma_i + \delta_i infra_{i,s-1} + \psi_{ijt}$$

where $\bar{T}'_{i,s} = (1/N)\sum_j \mathbf{T}'_{ij,s}\hat{\beta}$

Two-step approach

	(1)	(2)	(3)	(4)	(5)
	First stage: Gravity estimation	Second stage: Exporter	Second stage: Importer	Second stage: Exporter	Second stage: Importer
$gdppc_{s-1}$		0.90***	0.66***	0.87***	0.72***
		(0.10)	(0.11)	(0.11)	(0.14)
pop_{s-1}		1.17***	0.81***	0.76***	1.18***
		(0.15)	(0.17)	(0.21)	(0.22)
$dist^{hinz}_{ij,s-1}$	-1.10***				
	(0.19)				
$rta_{ij,s-1}$	0.29***				
	(0.05)				
$cu_{ij,s-1}$	0.55***				
	(0.04)				
$infra_{s-1}$		0.08**	0.30**	0.07*	0.49**
		(0.04)	(0.02)	(0.04)	(0.10)
$GL\ infra_{ij,s-1}$	0.79***				
	(0.10)				
$tariffs_{s-1}$				-0.01	-0.05*
				(0.02)	(0.03)
rol_{s-1}				0.05	0.02
				(0.07)	(0.12)
$\bar{T}_{s-1}$		-0.53*	-1.25	-1.11***	-1.43
		(0.30)	(1.84)	(0.22)	(1.49)
$Constant$		-19.17***	-11.83***	-12.46***	-18.46***
		(2.77)	(3.20)	(3.83)	(3.99)
No. of observations	307,286	2,536	2,536	1,414	1,414
R^2	0.99	0.64	0.62	0.60	0.57
Pair-fixed effects	yes	no	no	no	no
Country-time FE	yes	no	no	no	no
Country-fixed effects	no	yes	yes	yes	yes
Time-fixed effects	no	yes	yes	yes	yes

Two-step approach

	(1) First stage: Gravity estimation	(2) Second stage: Exporter	(3) Second stage: Importer	(4) Second stage: Exporter	(5) Second stage: Importer
$gdppc_{s-1}$		0.90***	0.66***	0.87***	0.72***
		(0.10)	(0.11)	(0.11)	(0.14)
pop_{s-1}		1.17***	0.81***	0.76***	1.18***
		(0.15)	(0.17)	(0.21)	(0.22)
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	(0.19)				
$rta_{ij,s-1}$	0.29***				
	(0.05)				
$cu_{ij,s-1}$	0.55***				
	(0.04)				
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Country-time FE	yes	no	no	no	no
Country-fixed effects	no	yes	yes	yes	yes
Time-fixed effects	no	yes	yes	yes	yes

Disentangle Trade Cost

- two ways to derive bilateral trade cost
  - trade cost calibration (odds-ratio method by Head and Ries (2010), Jacks et al (2011), Novy(2013))
    - tariff equivalent measure

$$\tau_{ij} \equiv \left(\frac{t_{ij}\,t_{ji}}{t_{ii}\,t_{jj}}\right)^{1/2} - 1 = \left(\frac{X_{ij}X_{ji}}{X_{ii}X_{jj}}\right)^{1/2(\sigma-1)}$$

  - estimate trade costs:
    $\hat{t_{ij,s}} = exp(\mathbf{T'_{ij}}\hat{\beta} + \hat{\delta_{ij}}\,GL\_infra_{ij,s-1} + \hat{\mu_{ij}}) + \hat{\epsilon_{ij,s}}$

- determinants of trade costs

$$\tau_{ij,s} = exp(\mathbf{T}_{ij,s-1}\beta + \delta_i\,infra_{i,s-1} + \delta_j\,infra_{j,s-1} + \delta_{ij}\,GL\_infra_{ij,s-1} + \mu_{ij}) + \epsilon_{ij,s}$$

Bilateral Trade Cost

	(1) Calibrated trade costs	(2) Calibrated trade costs	(3) Calibrated trade costs	(4) Calibrated trade costs	(5) Estimated trade costs	(6) Estimated trade costs	(7) Estimated trade costs	(8) Estimated trade costs
$dist^{hinz}_{ij,s-1}$	-0.12***	-0.13***	-0.25***	-0.16***	-1.10***	-1.10***	-1.10***	-1.10***
	(0.02)	(0.02)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
$rta_{ij,s-1}$	0.02***	0.02***	0.11***	0.07***	0.29***	0.29***	0.29***	0.29***
	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
$cu_{ij,s-1}$	0.04***	0.05***	0.02***	-0.00	0.55***	0.55***	0.55***	0.55***
	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
$infra_{i,s-1}$	0.03***	0.04***	0.20***	0.22***	0.63***	0.37***	0.16***	0.23***
	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
$infra_{j,s-1}$	0.02***	0.03***	0.19***	0.21***	0.66***	0.39***	0.16***	0.24***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$GL\ infra_{ij,s-1}$	-0.04***	-0.05***	-0.09***	-0.06***	0.79***	0.79***	0.79***	0.79***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
$comlang_{ij}$			0.05***	0.07***			0.45***	0.53***
			(0.01)	(0.01)			(0.01)	(0.02)
$contig_{ij}$			0.13***	0.13***			1.19***	1.30***
			(0.01)	(0.01)			(0.02)	-0.03
$colony_{ij}$			0.19***	0.16***			0.25***	0.39***
			(0.01)	(0.01)			(0.04)	(0.04)
$tariffs_{i,s-1}$		-0.02***		0.00		-0.11***		-0.01***
		(0.00)		(0.00)		(0.01)		(0.00)
$tariffs_{j,s-1}$		-0.01***		0.00		-0.11***		-0.01***
		(0.00)		(0.00)		(0.00)		(0.01)
$rol_{i,s-1}$		0.01**		-0.00		0.02***		0.00
		(0.00)		(0.00)		(0.01)		(0.07)
$rol_{j,s-1}$		0.02***		-0.00		0.02***		0.01
		(0.00)		(0.00)		(0.00)		(0.01)
$Constant$	4.40***	4.16***	3.76***	3.56***	20.78***	14.55	7.90***	7.71***
	(0.19)	(0.16)	(0.06)	(0.01)	(0.19)	(0.00)	(0.08)	(0.07)
No. of observations	219,930	102,303	219,930	102,303	291,703	119,768	291,703	119,768
R^2	0.27	0.38	0.40	0.45	0.86	0.91	0.76	0.78
Pair-fixed effects	yes	yes	no	no	yes	yes	no	no
Country-fixed effects	no	no	yes	yes	no	no	yes	yes
Time-fixed effects	yes	yes	yes	yes	yes	yes	yes	yes

Bilateral Trade Cost

	(1) Calibrated trade costs	(2) Calibrated trade costs	(3) Calibrated trade costs	(4) Calibrated trade costs	(5) Estimated trade costs	(6) Estimated trade costs	(7) Estimated trade costs	(8) Estimated trade costs
$dist^{hinz}_{ij,s-1}$	-0.12***	-0.13***	-0.25***	-0.16***	-1.10***	-1.10***	-1.10***	-1.10***
	(0.02)	(0.02)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
$rta_{ij,s-1}$	0.02***	0.02***	0.11***	0.07***	0.29***	0.29***	0.29***	0.29***
	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
$cu_{ij,s-1}$	0.04***	0.05***	0.02***	-0.00	0.55***	0.55***	0.55***	0.55***
	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
$infra_{i,s-1}$	0.03***	0.04***	0.20***	0.22***	0.63***	0.37***	0.16***	0.23***
	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
$infra_{j,s-1}$	0.02***	0.03***	0.19***	0.21***	0.66***	0.39***	0.16***	0.24***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$GL\ infra_{ij,s-1}$	-0.04***	-0.05***	-0.09***	-0.06***	0.79***	0.79***	0.79***	0.79***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
$comlang_{ij}$			0.05***	0.07***			0.45***	0.53***
			(0.01)	(0.01)			(0.01)	(0.02)
$rol_{j,s-1}$		0.02***		-0.00		0.02***		0.01
		(0.00)		(0.00)		(0.00)		(0.01)
$Constant$	4.40***	4.16***	3.76***	3.56***	20.78***	14.55	7.90***	7.71***
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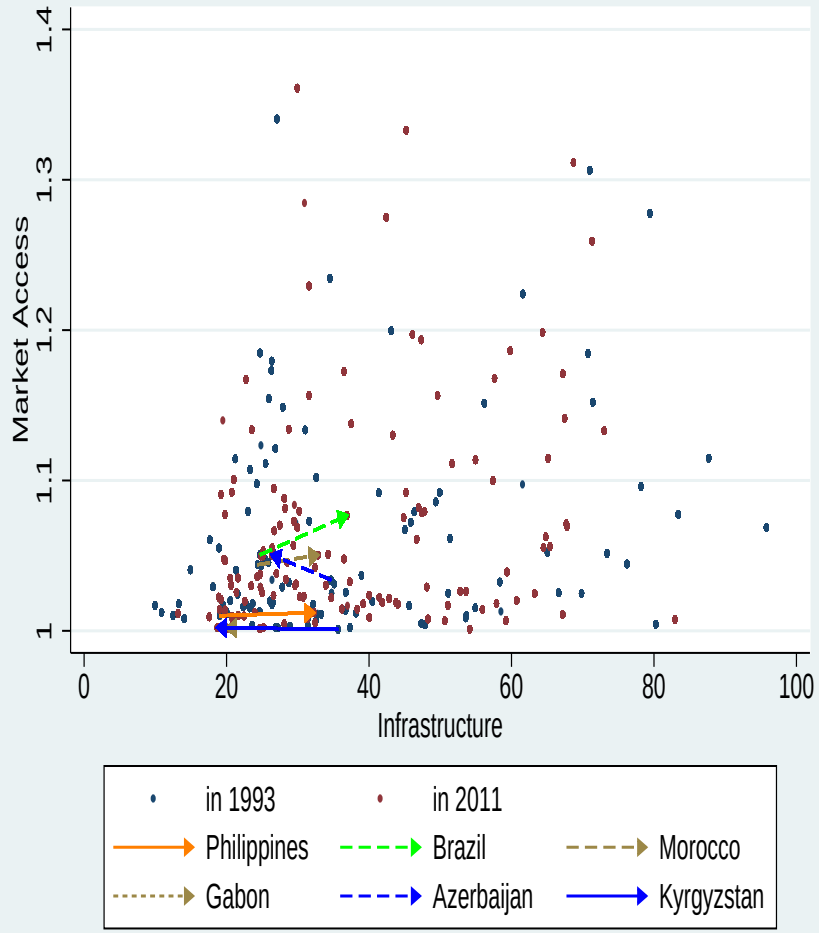
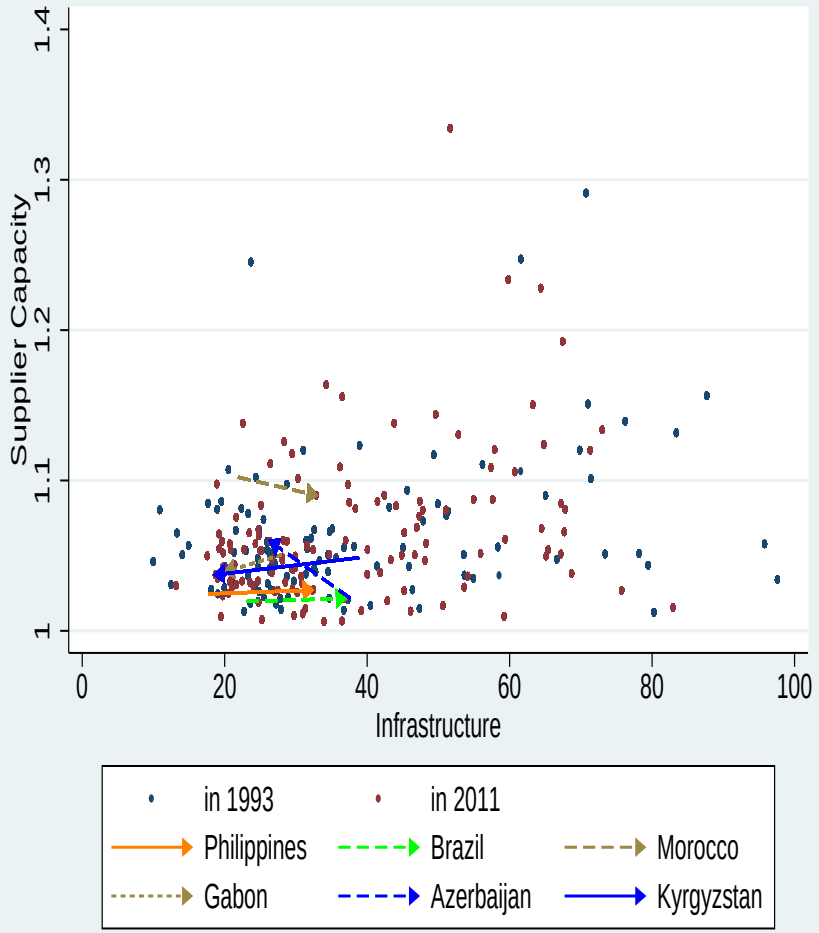
Pair-fixed effects	yes	yes	no	no	yes	yes	no	no
Country-fixed effects	no	no	yes	yes	no	no	yes	yes
Time-fixed effects	yes	yes	yes	yes	yes	yes	yes	yes

Average Trade Cost

- multilateral trade costs can be derived following Larch and Yotov (2016) ▸ details
- Change from 1993 to 2011 for selected countries





Intra- vs. International Trade

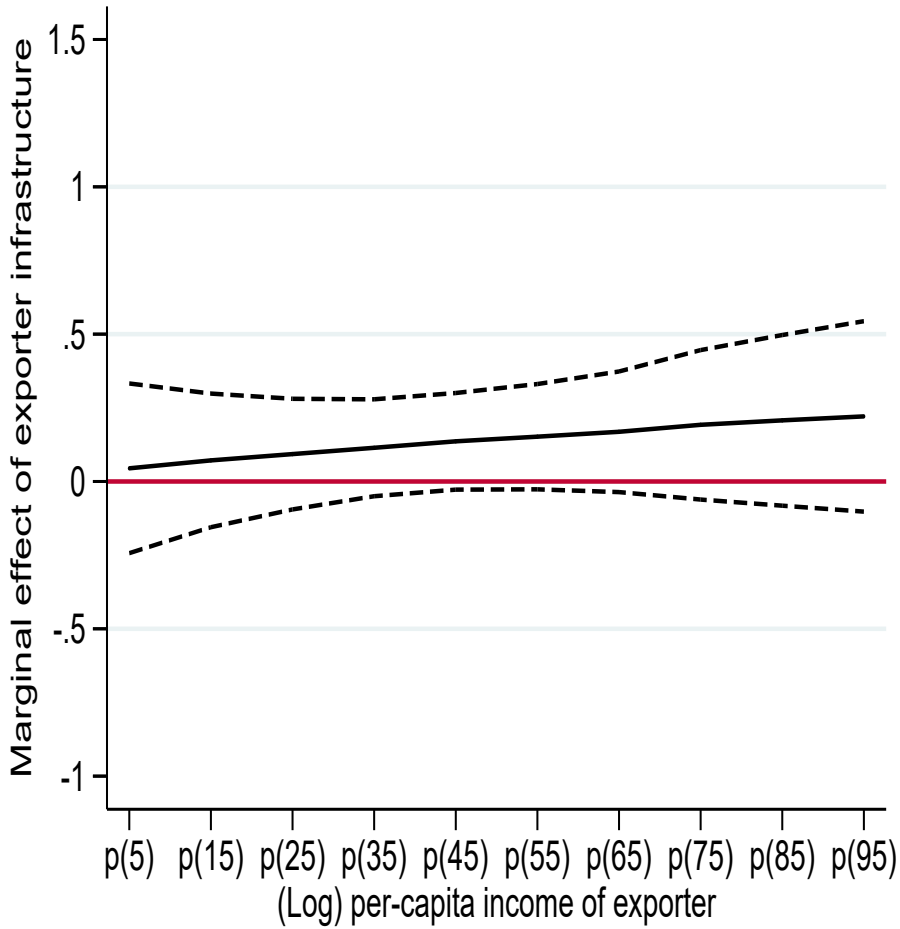
- add internal trade and internal distances to explicitly account for intra-national trade

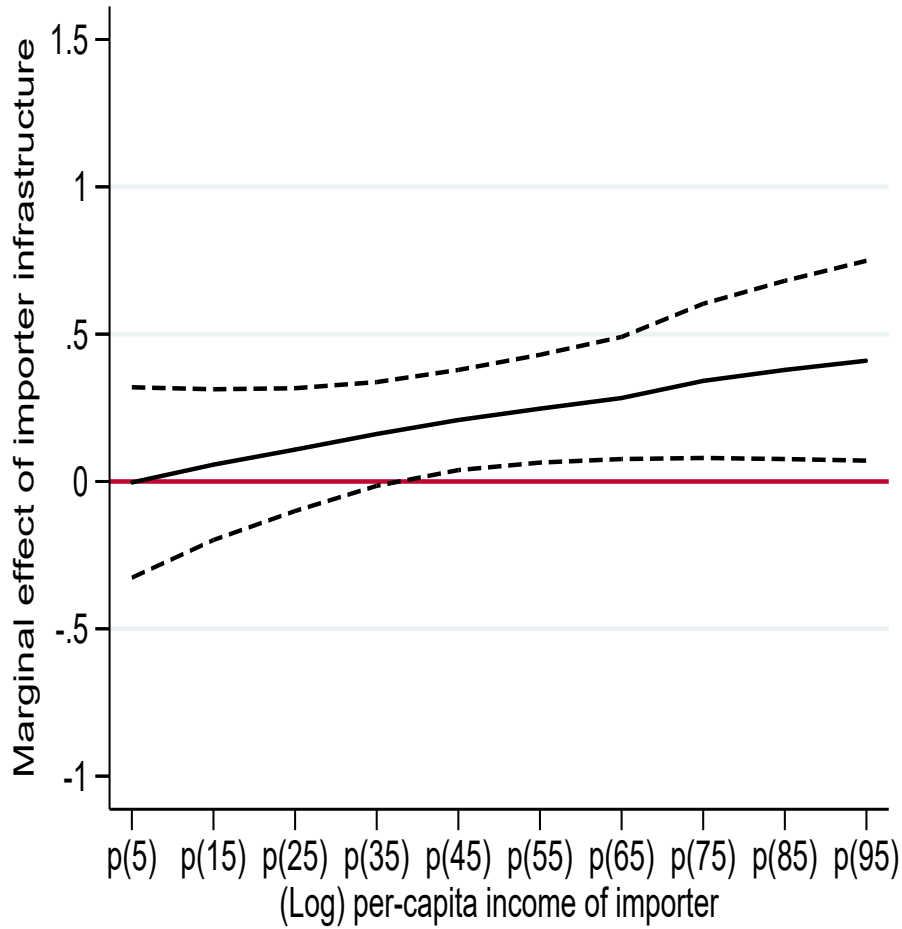
$$X_{ijs} = exp(\mathbf{T}'_{ij,s-1}\beta + \mathbf{C}'_{i,s-1}\gamma_1 + \mathbf{C}'_{j,s-1}\gamma_2 + \delta_i infra_{i,s-1} + \delta_j infra_{j,s-1} + \delta_{ij} GL\_infra_{ij,s-1} + \mu_{ij}) + exp(\delta_0 intra_{ii} + \delta_{0i} intra_{ii} x infra_{i,s-1}) + \epsilon_{ijs}$$

	(1)	(2)	(3)	(4)
	Intra- vs. international trade			
$infra_{i,s-1}$	0.20**	1.04***	0.20**	1.06***
	(0.09)	(0.11)	(0.09)	(0.12)
$infra_{j,s-1}$	0.31***	1.05***	0.31***	1.07***
	(0.09)	(0.12)	(0.09)	(0.12)
$GL\ infra_{ij,s-1}$	0.72***	0.25	0.72***	0.28*
	(0.12)	(0.16)	(0.12)	(0.16)
$intra_{ii}$		10.68***		9.86***
		(0.54)		(0.67)
$intra_{ii} \times infra_{i,s-1}$	-0.62***	-1.76***	-0.60***	-1.80***
	(0.19)	(0.11)	(0.19)	(0.12)
$intra_{ii} \times dist^{hinz}_{ii,s-1}$			-0.90*	0.14*
			(0.49)	(0.08)
No. of observations	291,703	291,703	291,703	291,703
Pair-fixed effects	yes	no	yes	no
Country-fixed effects	no	yes	no	yes
Time-fixed effects	yes	yes	yes	yes

Interaction with Income

- Does the importance of infrastructure for trade vary with per capita income?





Infrastructure Categories

	(1) Total Infrastructure	(2) Transport	(3) Communication	(4) Energy	(5) Finance
Infra_i	0.16*	0.26***	0.40***	-0.05	0.04
	(0.09)	(0.06)	(0.05)	(0.13)	(0.05)
Infra_j	0.26***	0.27***	0.16	-0.06	0.23***
	(0.10)	(0.06)	(0.05)	(0.13)	(0.05)
GL Infra	0.67***	0.04	0.55***	-0.00	0.10
	(0.13)	(0.06)	(0.08)	(0.15)	(0.07)
Observations	291,703	335,199	329,506	242,302	241,212
Number of pv	18,783	19,012	19,024	13,644	18,436
Pair FE	YES	YES	YES	YES	YES
Country FE	NO	NO	NO	NO	NO
Time FE	YES	YES	YES	YES	YES

Trade Categories

	(1) Intermediate goods	(2) Capital goods	(3) Consumption goods
$gdppc_{i,s-1}$	0.77***	1.18***	0.81***
	(0.13)	(0.18)	(0.11)
$gdppc_{j,s-1}$	0.72***	0.54***	0.32*
	(0.13)	(0.18)	(0.17)
$pop_{i,s-1}$	0.86**	1.44**	0.51
	(0.42)	(0.63)	(0.46)
$pop_{j,s-1}$	0.34	1.40**	1.12**
	(0.44)	(0.64)	(0.44)
$dist_{ij,s-1}^{hinz}$	-0.09	0.25	0.03
	(0.71)	(0.86)	(0.65)
$rta_{ij,s-1}$	0.24***	0.44***	0.19***
	(0.05)	(0.08)	(0.06)
$cu_{ij,s-1}$	0.50***	0.57***	0.53***
	(0.04)	(0.06)	(0.06)
$infra_{i,s-1}$	0.42***	0.32	-0.25
	(0.14)	(0.23)	(0.15)
$infra_{j,s-1}$	0.35**	0.61***	0.82***
	(0.14)	(0.22)	(0.16)
$GL\ infra_{ij,s-1}$	0.98***	0.71**	0.50**
	(0.23)	(0.33)	(0.23)
No. of observations	24,173	24,173	24,173
Pair-fixed effects	yes	yes	yes
Country-fixed effects	no	no	no
Time-fixed effects	yes	yes	yes

Trade Categories

	(1) Intermediate goods	(2) Capital goods	(3) Consumption goods
$gdppc_{i,s-1}$	0.77***	1.18***	0.81***
	(0.13)	(0.18)	(0.11)
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	(0.44)	(0.64)	(0.44)
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$infra_{i,s-1}$	0.42***	0.32	-0.25
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	(0.14)	(0.22)	(0.16)
$GL\ infra_{ij,s-1}$	0.98***	0.71**	0.50**
	(0.23)	(0.33)	(0.23)
No. of observations	24,173	24,173	24,173
Pair-fixed effects	yes	yes	yes
Country-fixed effects	no	no	no
Time-fixed effects	yes	yes	yes

Other Robustness Checks

- extended lags
- excluding pairs with major trading partners

Conclusion

- overall there are significant positive effects of infrastructure on trade
- the choice between domestic and international sourcing critically depends on the importing country's infrastructure
- improving infrastructure reduces trade cost: similarly strong effects on bilateral trade costs for the exporter and the importer
- countries with improved infrastructure reduced not only bilateral trade costs but also multilateral trade costs (i.e. average trade costs with all other trading partners).
- a good mix of infrastructure is what matters most for promoting bilateral trade
- missing infrastructure explains part of missing trade flows

Outlook: Effects on FDI

- similar approach for FDI using a micro-founded gravity FDI framework resembling the trade gravity model

$$FDI_{ij} = \begin{cases} \frac{\beta\phi^2\eta_i^2}{1-\beta+\beta\delta_M}\omega_{ij}\frac{E_i}{P_i}\frac{Y_j}{M_i} & \text{if } FDI_{ij} > 1 \\ 0 & \text{if } FDI_{ij} \leq 1 \end{cases}$$

- significant positive effects of infrastructure on FDI
- Hypothesis: infrastructure reduces investment frictions in developing countries

Appendix

- Infrastructure Indicators
- UCM
- Infrastructure maps
  - Transport maps
  - ICT maps
  - Energy maps
  - Finance maps

Multilateral Trade Cost

- Solving the gravity framework for the multilateral resistance terms requires a normalization of the multilateral resistance terms.
- normalization corresponding to U.S. fixed effects
- following Anderson et al. (2015) and Larch and Yotov (2016), we recover the outward and inward multilateral trade costs as

$$\hat{\Pi}_{i,s}^{1-\sigma} = Y_{i,s} exp(-\hat{\eta}_{i,s}) E_{US,s}$$

and

$$\hat{P}_{i,s}^{1-\sigma} = E_{j,s} exp(-\hat{\theta}_{j,s}) 1/E_{US,s}$$

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Transport Infrastructure

Land	Roads, total network	km/area	World Bank/ IRF
	Roads paved	% of total roads	World Bank/ IRF
	Motorways	% of total roads	IRF
	Registered passenger cars	p.c.	VDA
	Commercial vehicles	p.c.	VDA
	Railways, good transported	tons*km/area	World Bank
	Rail lines	km/density	World Bank
	Railways, passengers carried	p.c.	World Bank
Air	Air transport, carrier departures	p.c.	World Bank
	Air transport, freight	tons*km/area	World Bank
Sea	Total ship carrying capacity	tons/area	UNCTAD
	Share of ship carrying capacity	% of world capacity	UNCTAD

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Information and Communication Technology

Telephone	Fixed telephone lines	p.c.	ITU
	Faults to fixed telephone lines	%, (-1)	ITU
	ISDN subscriptions	p.c.	ITU
	Mobile telephone subscriptions	p.c.	ITU
Computer & Internet	Internet users	p.c.	World Bank
	Personal Computers	p.c.	ITU

back

Energy

Production & Consumption	Electric power consumption	p.c.	World Bank
	Electric production	p.c.	World Bank
Availably & Quality	Electric power transmission and distribution losses	p.c.	World Bank

back

Finance

Access	Publicly listed companies	p.c.	Beck and Demirgüc-Kunt (2009)
	Bank Accounts	p.c.	GFDD
	Value traded	share traded outside of top ten companies in a stock market exchange, logged	GFDD
Depth	Stock market total value traded	shares traded/GDP, logged.	Beck and Demirgüc-Kunt (2009)
	Money and quasi money	% of GDP, logged	World Bank
Efficiency	Stock market turnover	shares traded/market capitalization, logged	GFDD
Stability	Bank Z-Score	logged	GFDD
	Stock price volatility	logged, (-1)	GFDD

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Unobserved Component Model (UCM)

$$y_{cj} = \alpha_j + \beta_j(I_c + \varepsilon_{cj}) \tag{4}$$

where:
- y_{cj} observed infrastructure score of country $c \in [1, C]$ and indicator $j \in [1, J]$; each indicator j is rescaled to range from 0 to 1
- I_c unobserved and imperfect measure of infrastructure; $I_c \sim N(0, 1)$
- ε_{cj} error term; i.i.d. with $E[\varepsilon_{cj}] = 0$, $var(\varepsilon_{cj}) = \sigma_j^2$ and $E[\varepsilon_{ci}\varepsilon_{cj}] = 0$ for $i \neq j$; I_c and ε_{cj} are jointly normally distributed

- Estimated by Maximum Likelihood subject to α_j, β_j and σ_j^2

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CalculationUnobserved Component Model (UCM)

- Our index is calculated as:

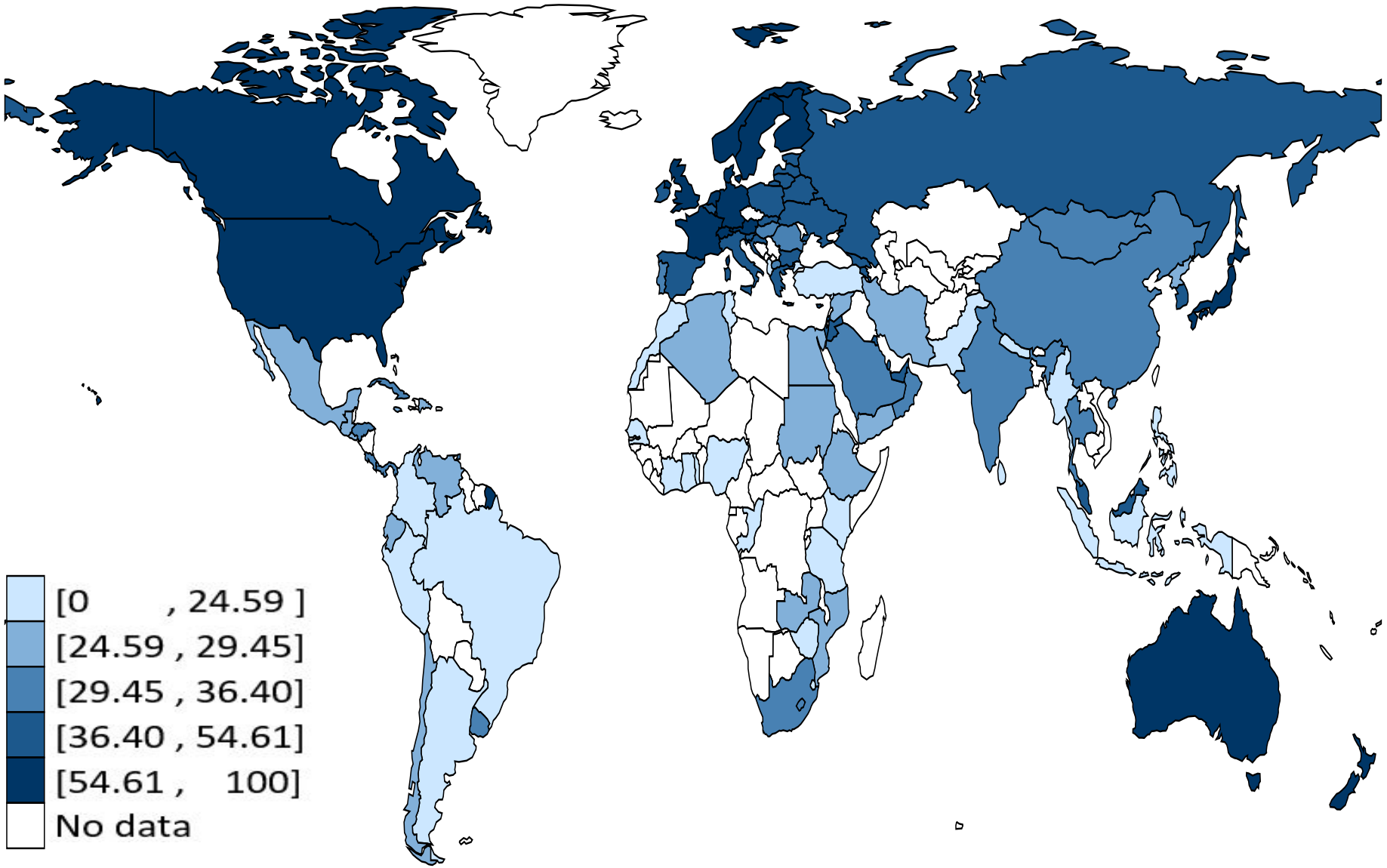
$$E[I_c \mid y_{c1}, \cdots, y_{cJ}] = \sum_{j=1}^{J} w_{cj} \frac{y_{cj} - \alpha_j}{\beta_j} \tag{5}$$

$$\text{with weight } w_{cj} = \frac{\sigma_j^{-2}}{1 + \sum_{j=1}^{J} \sigma_j^{-2}} \tag{6}$$

- Index $I_c \sim N(0, 1)$ in each period
- Time adjustment: Backward rescaling of I_c as if we had the same country sample relative to the following year

back

Overall Index, 1990



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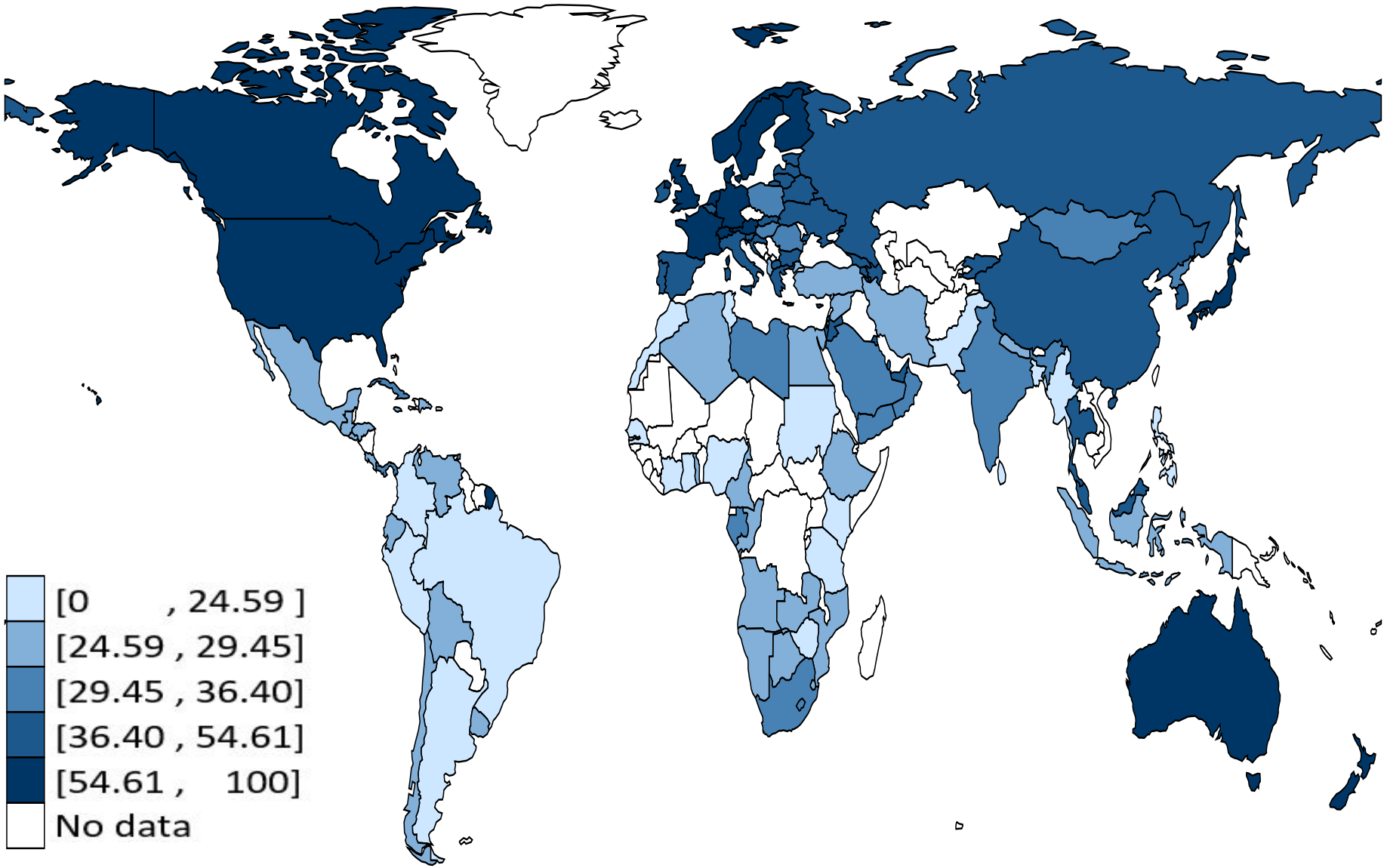

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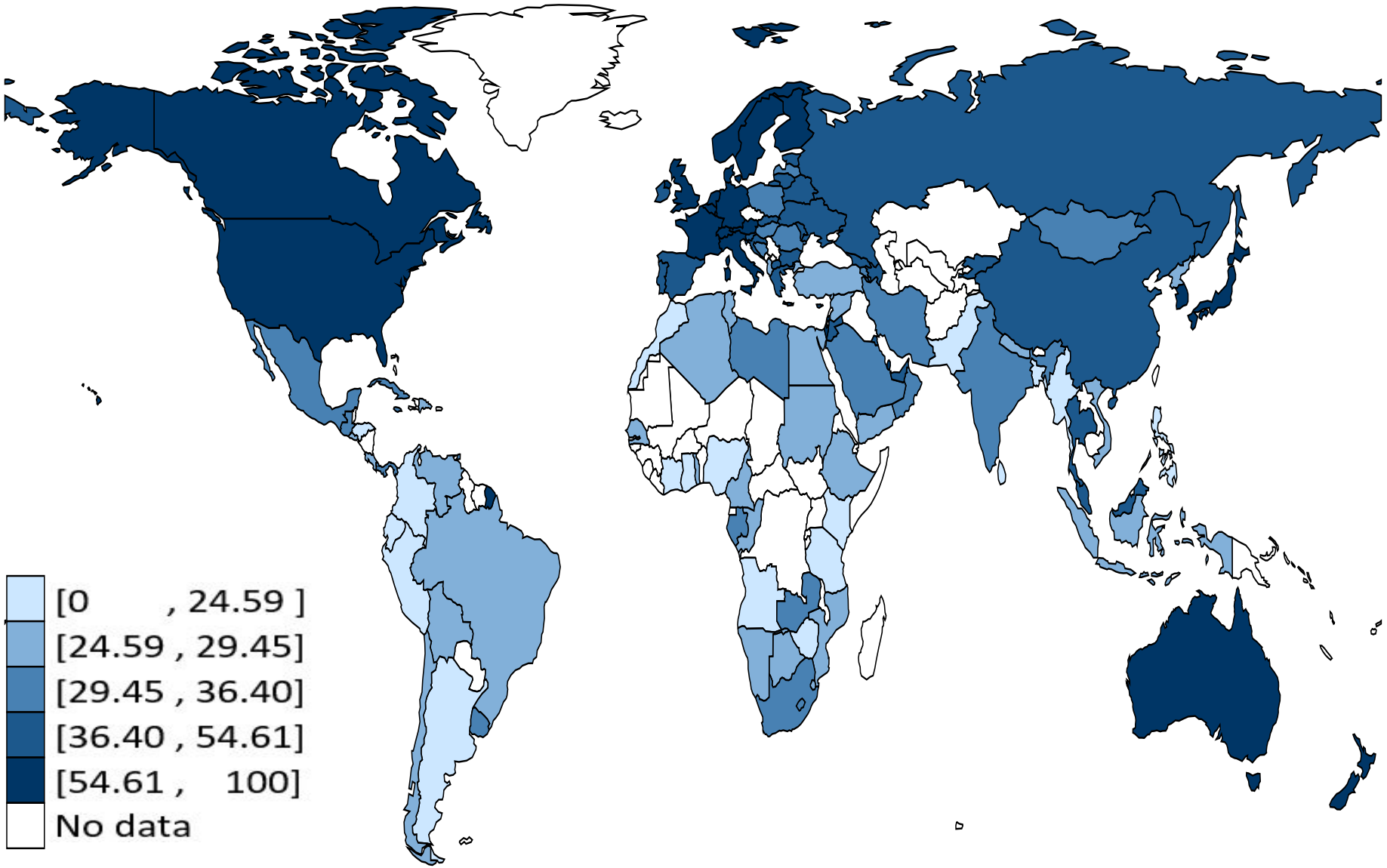

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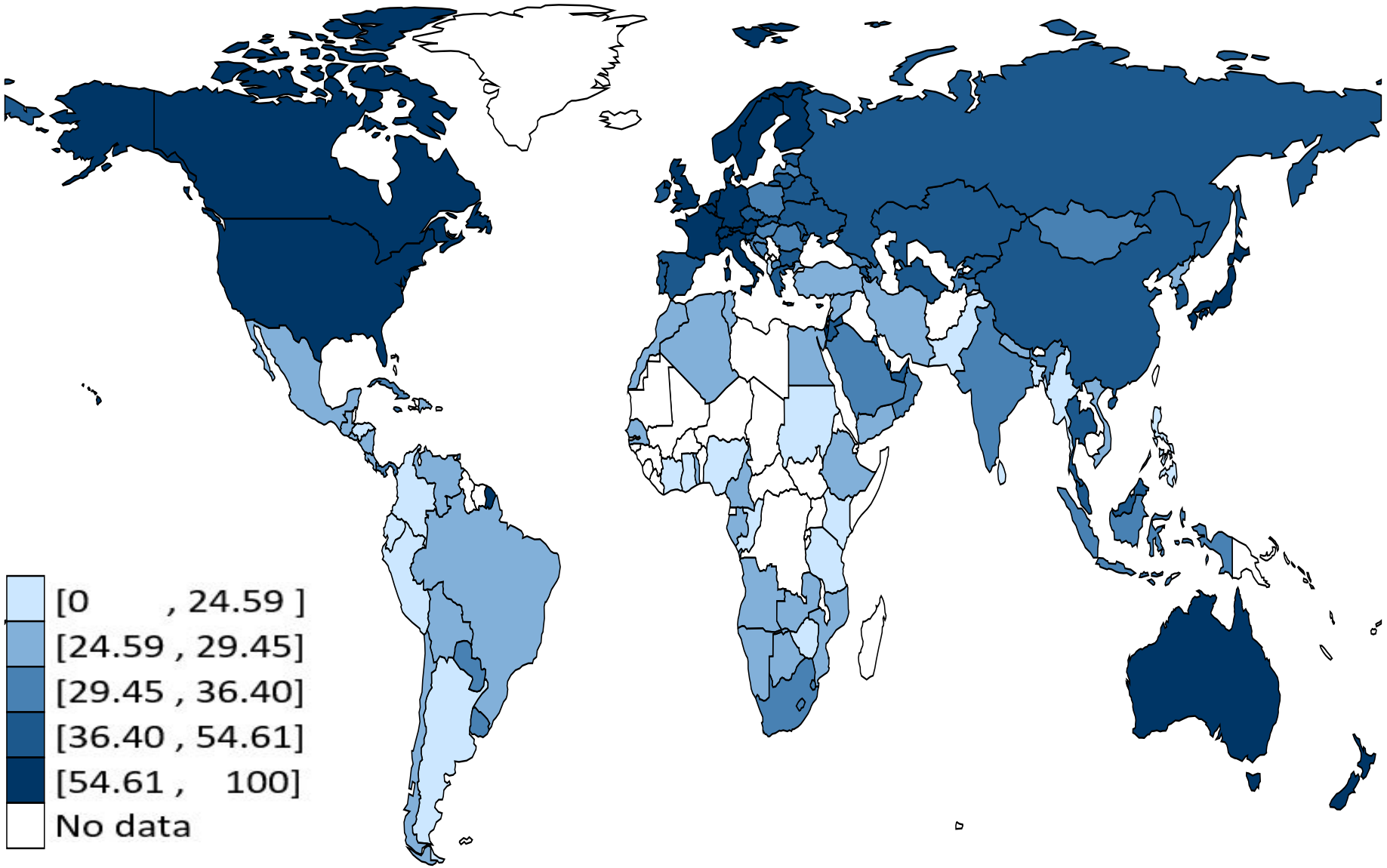

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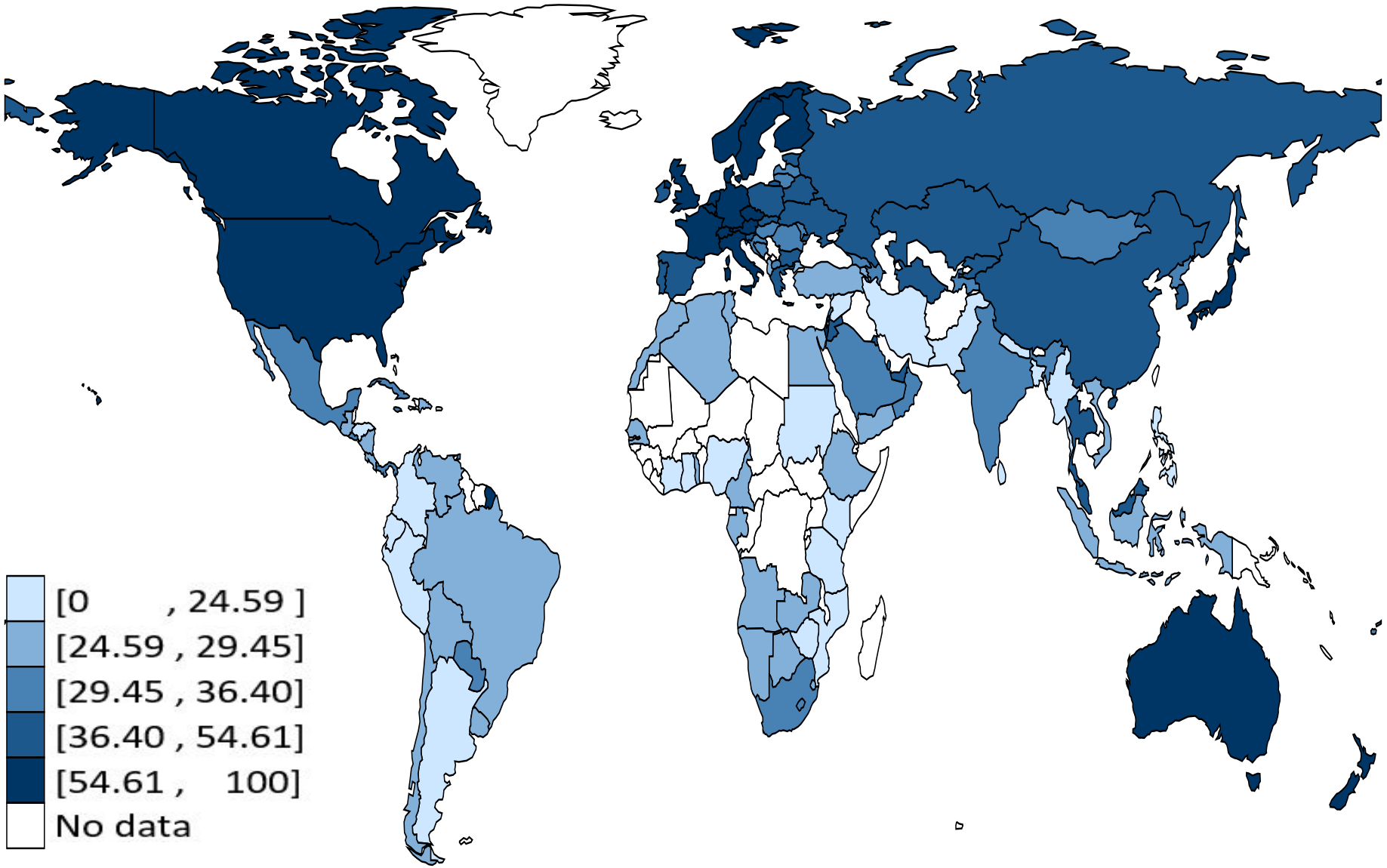

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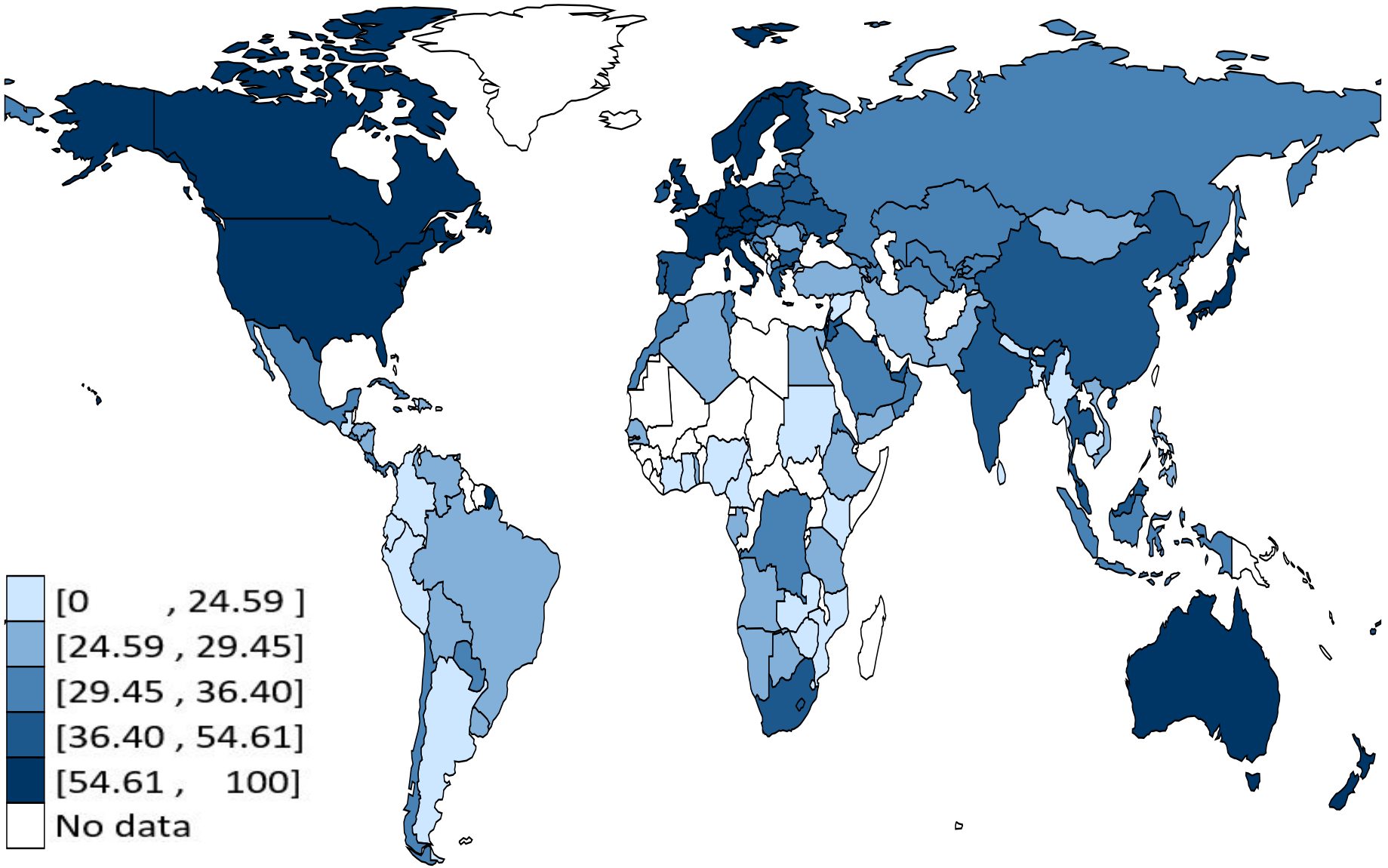

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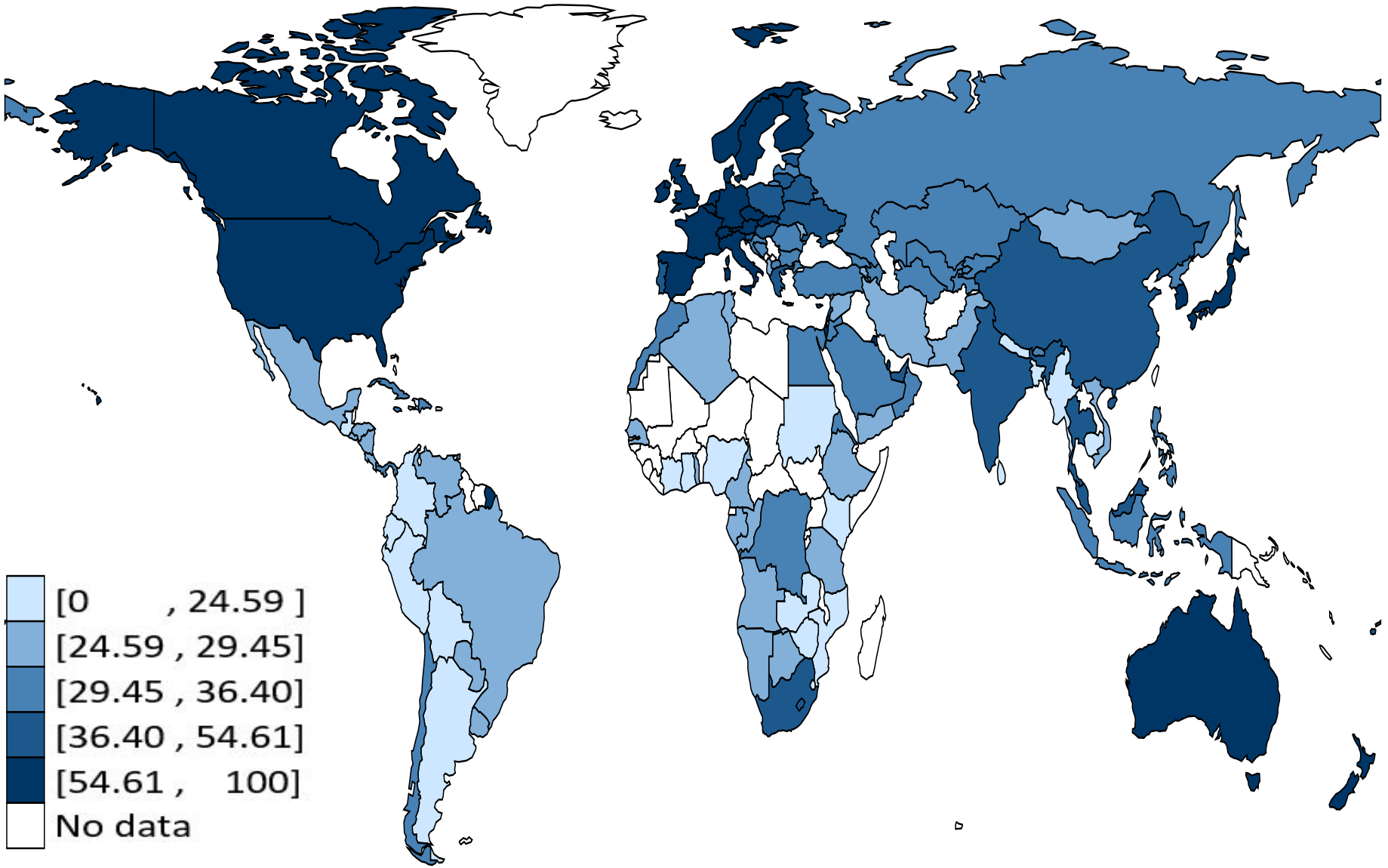

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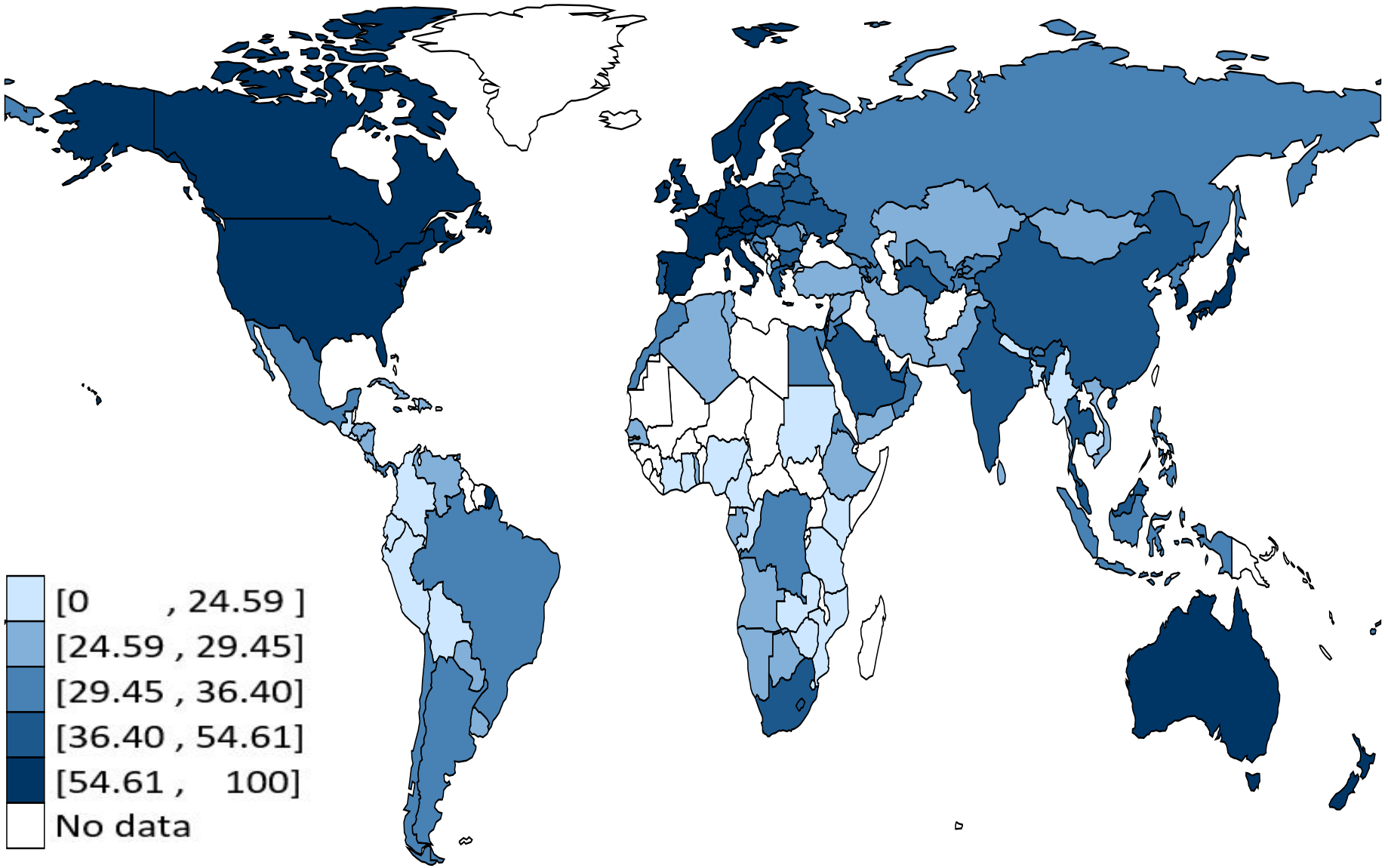

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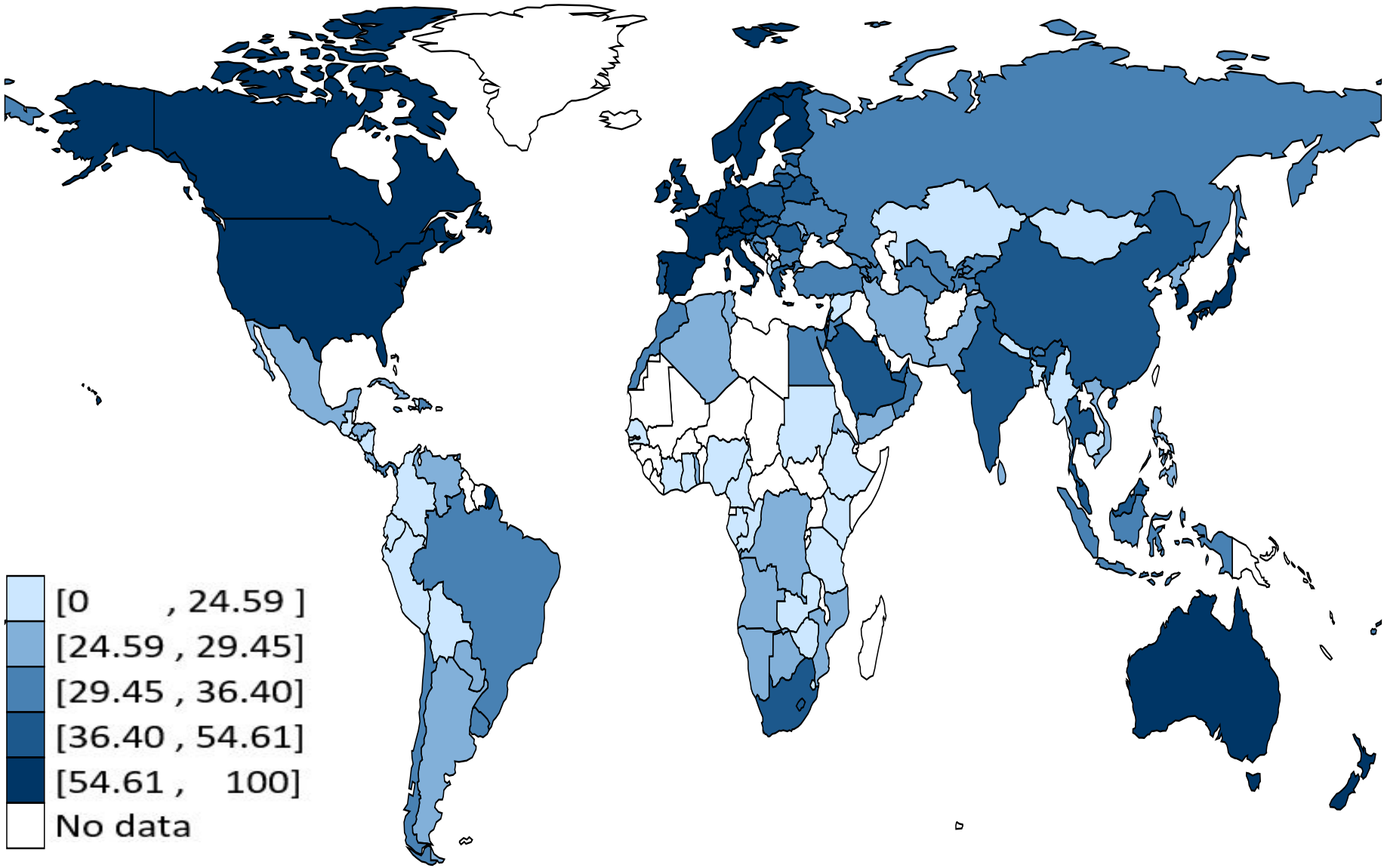

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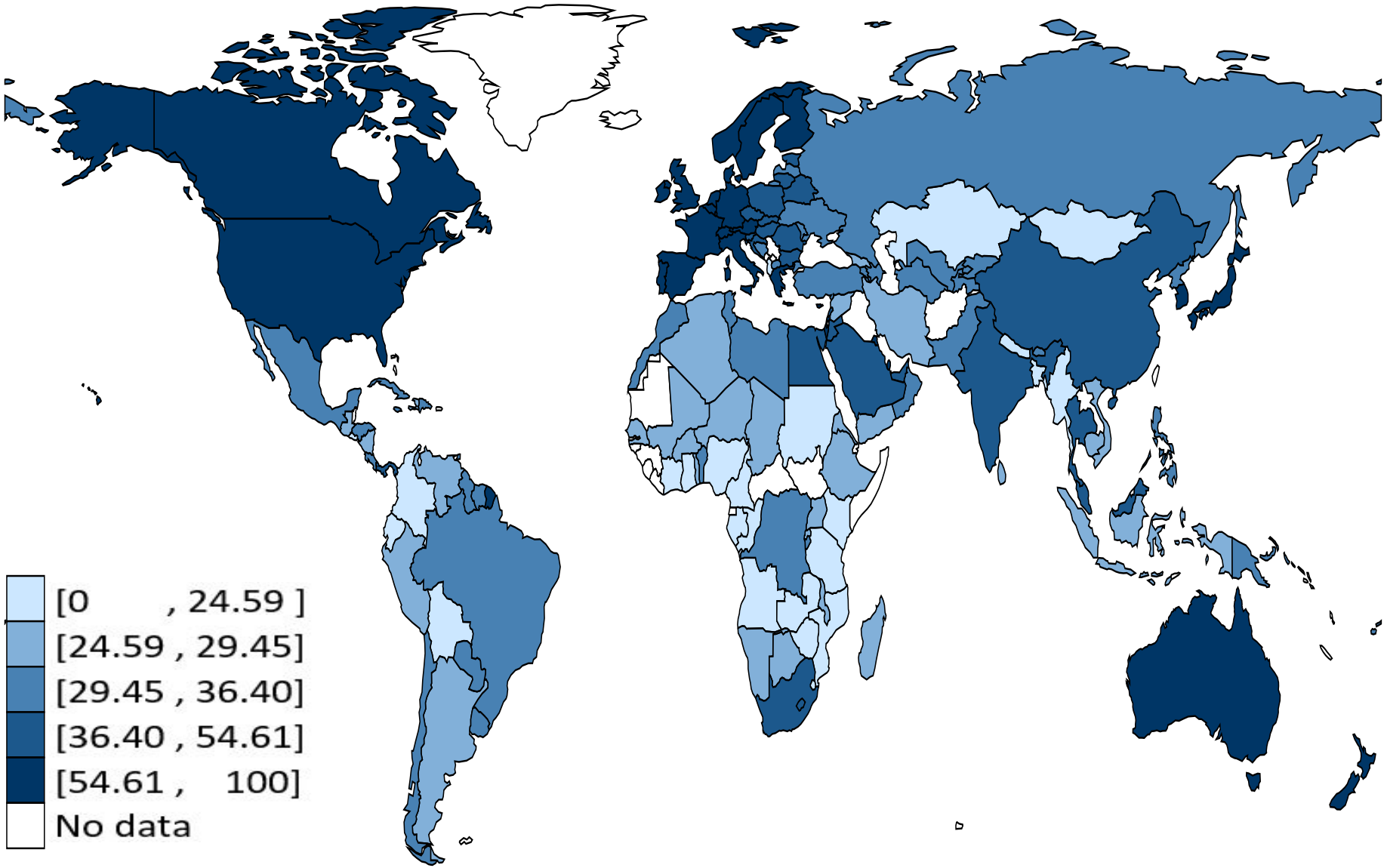

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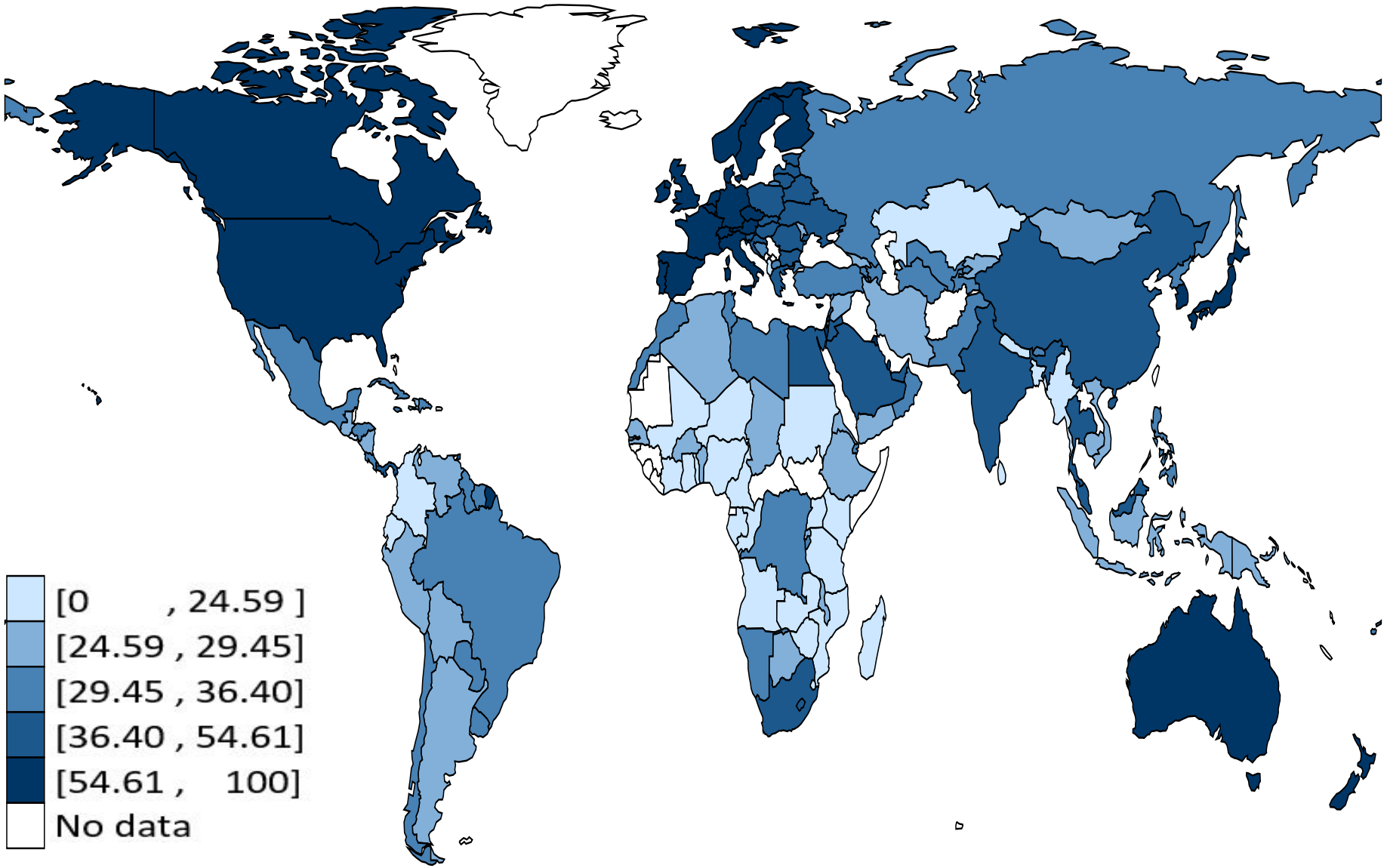

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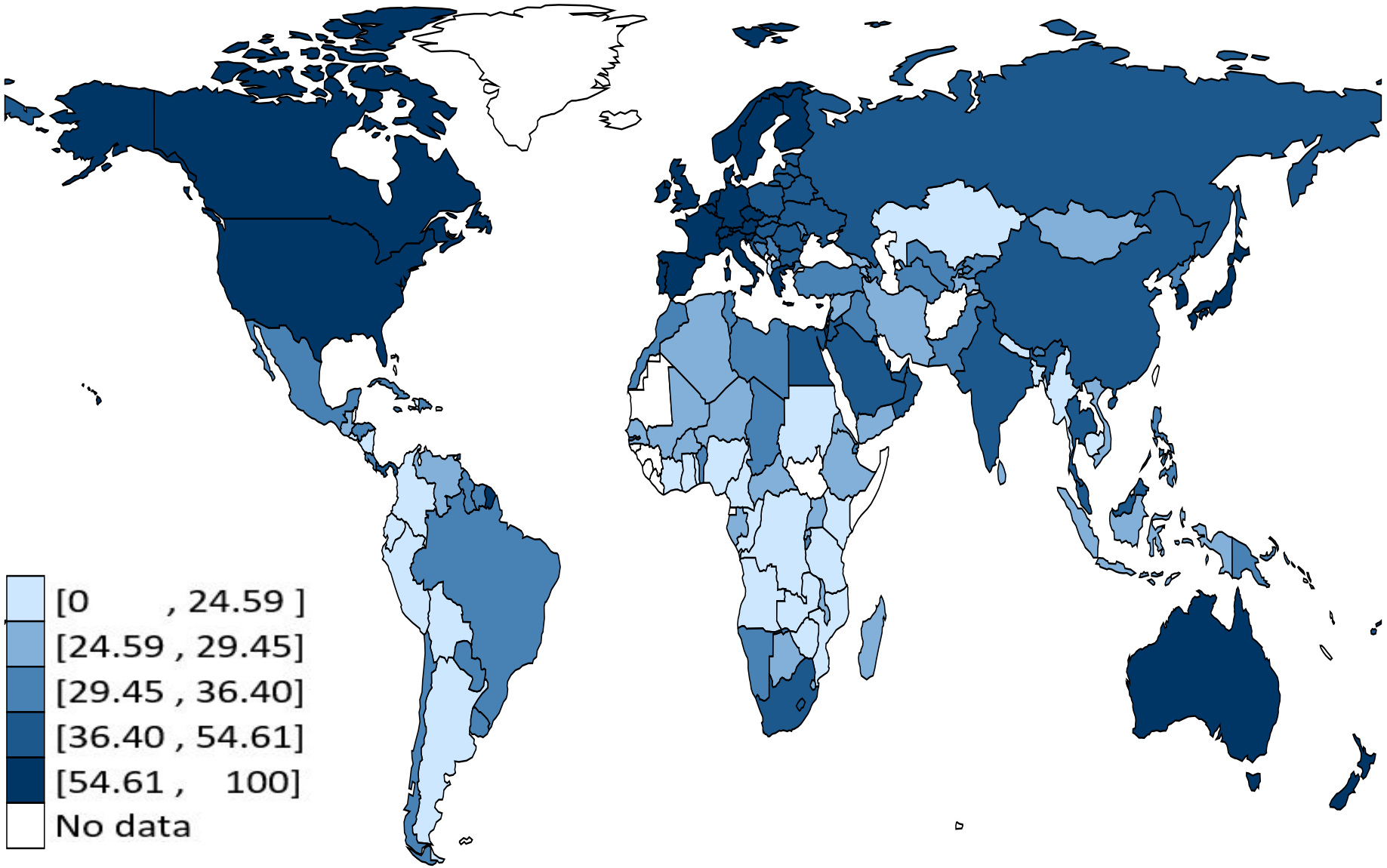

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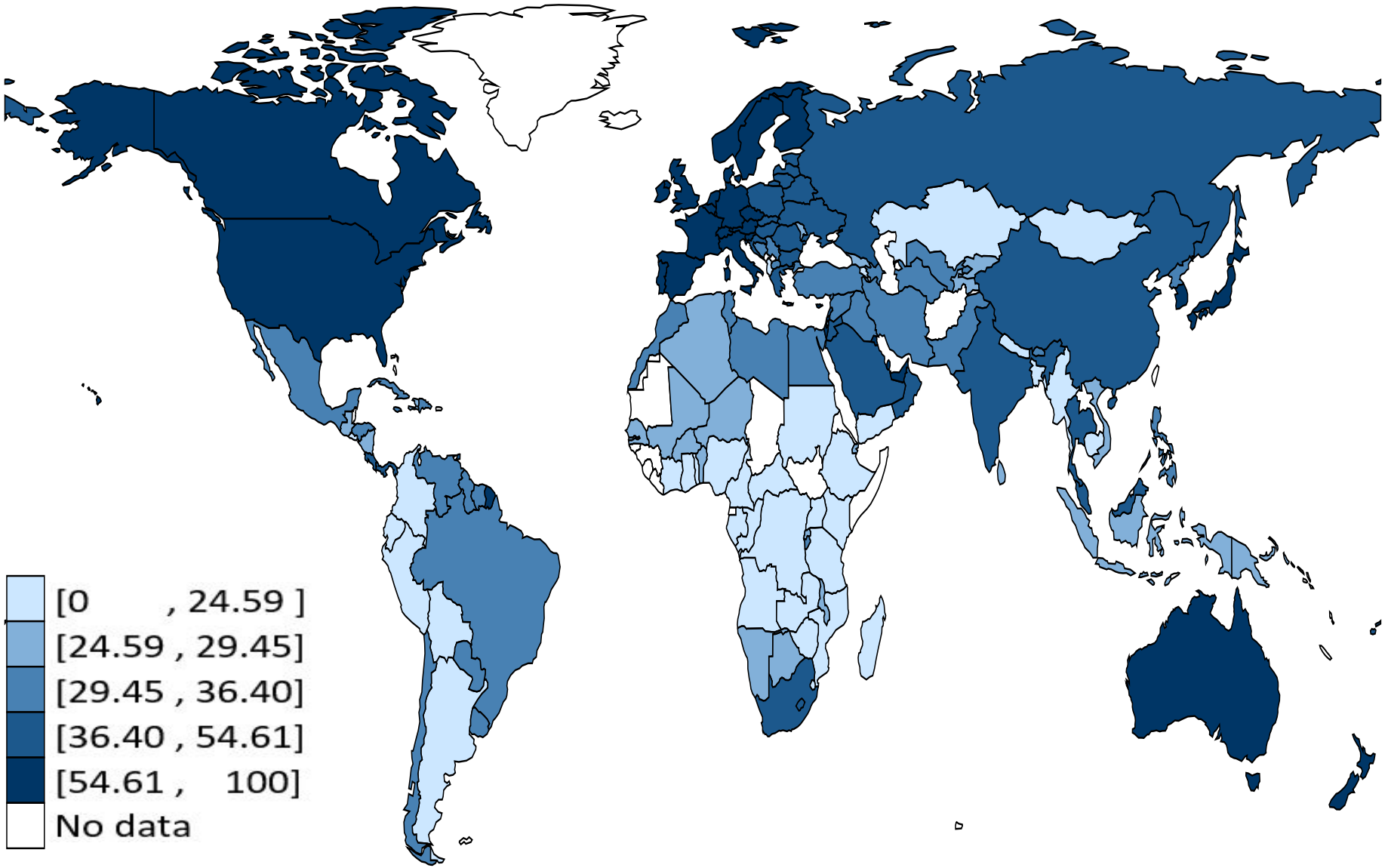

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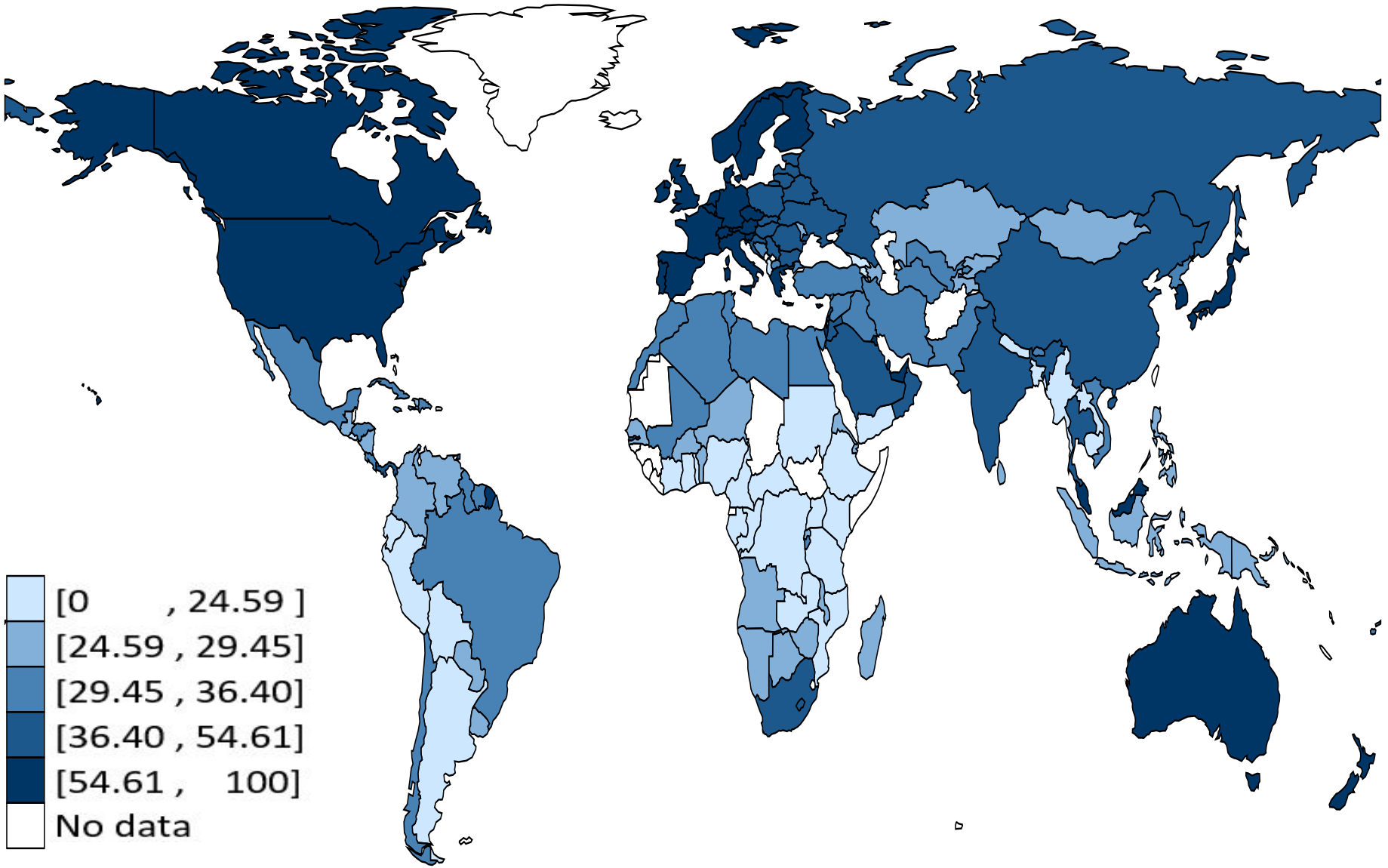

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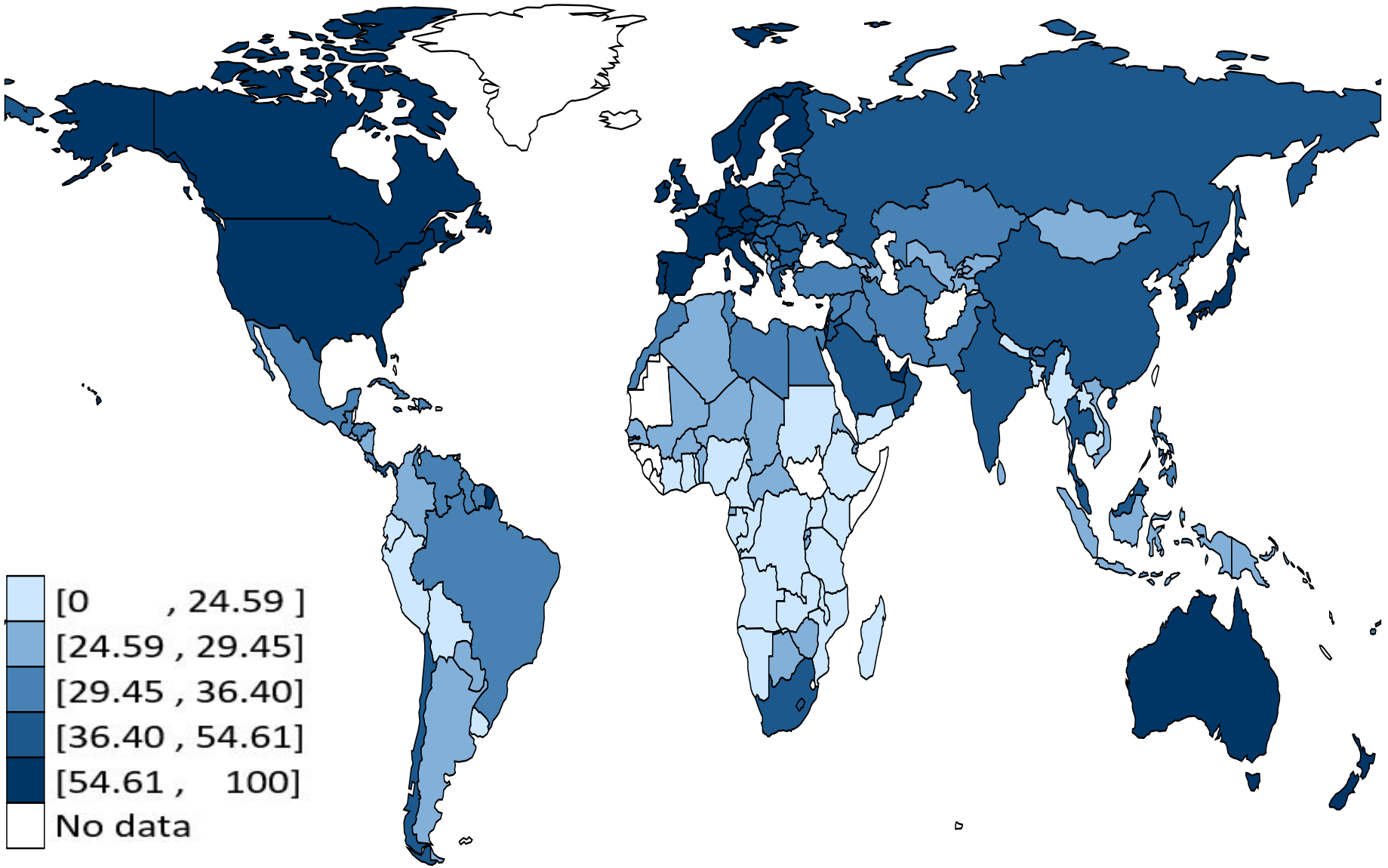

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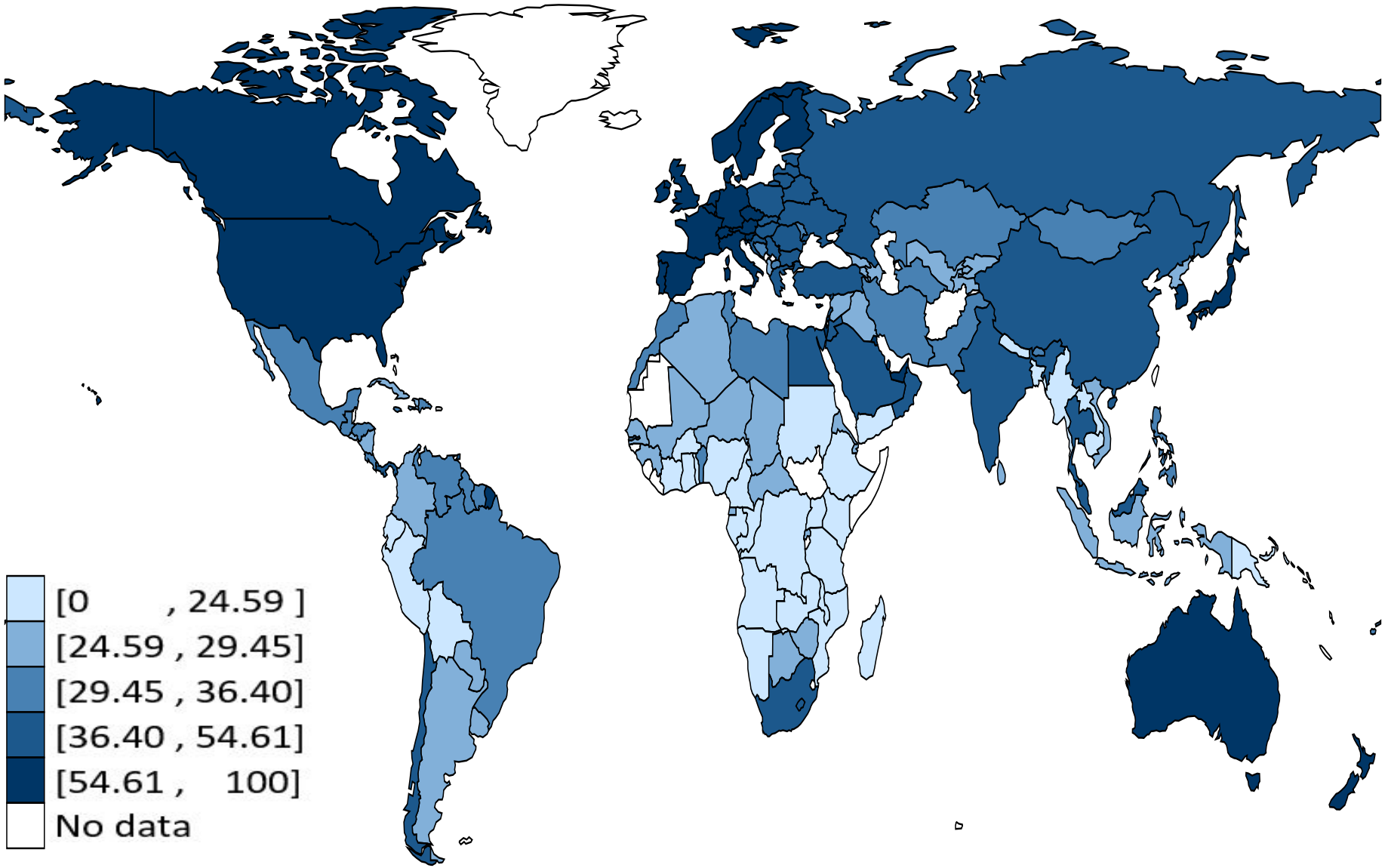

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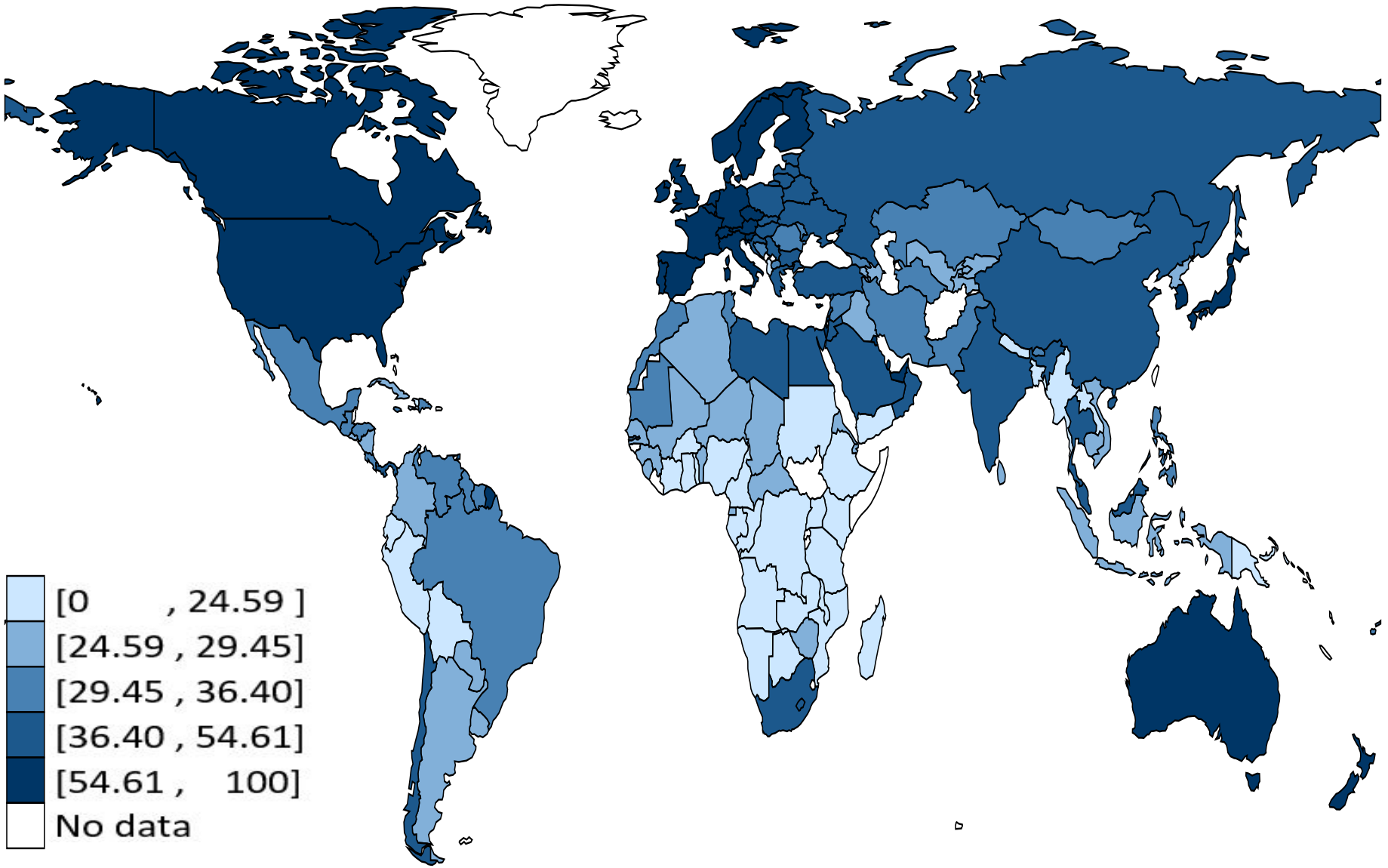

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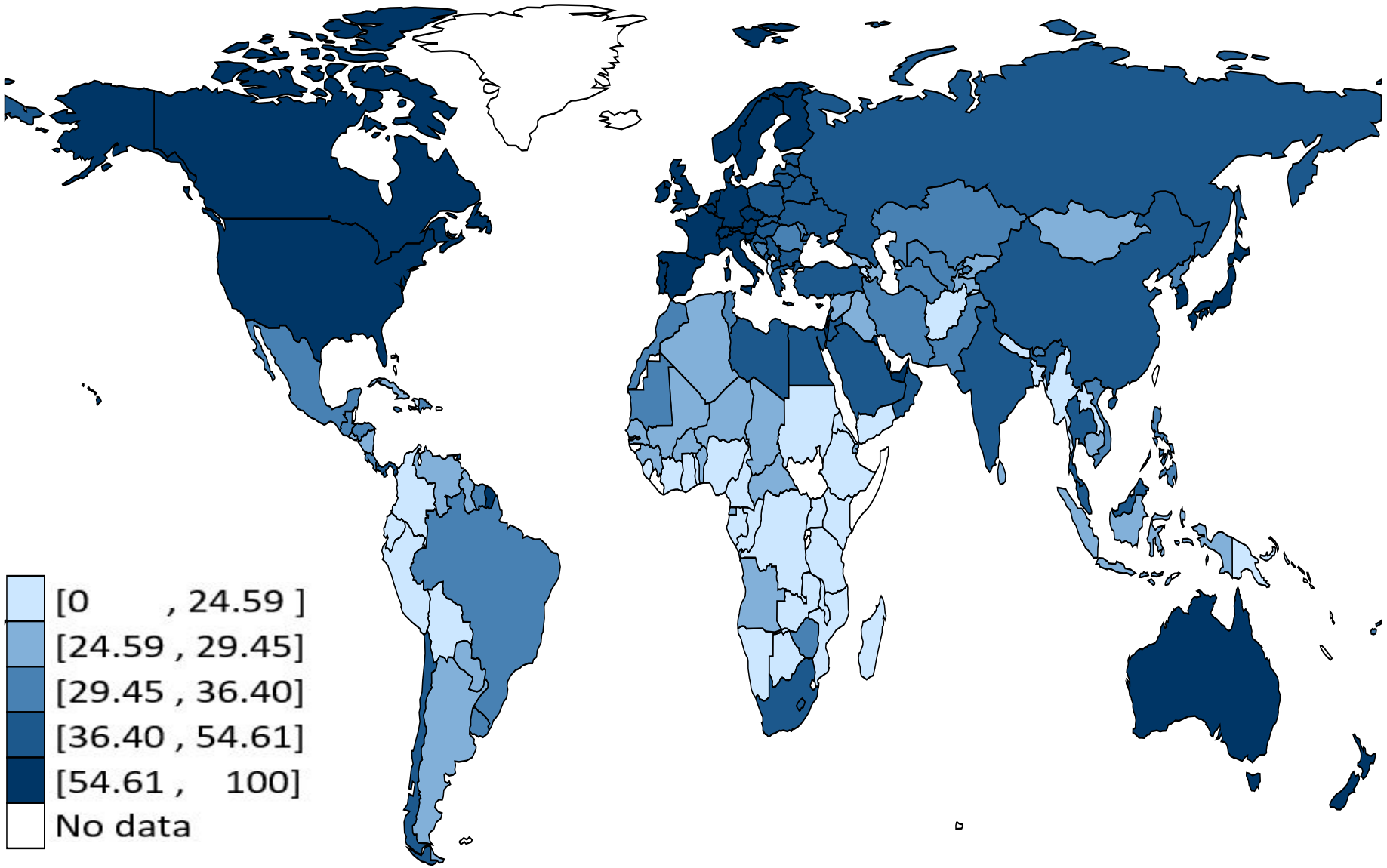

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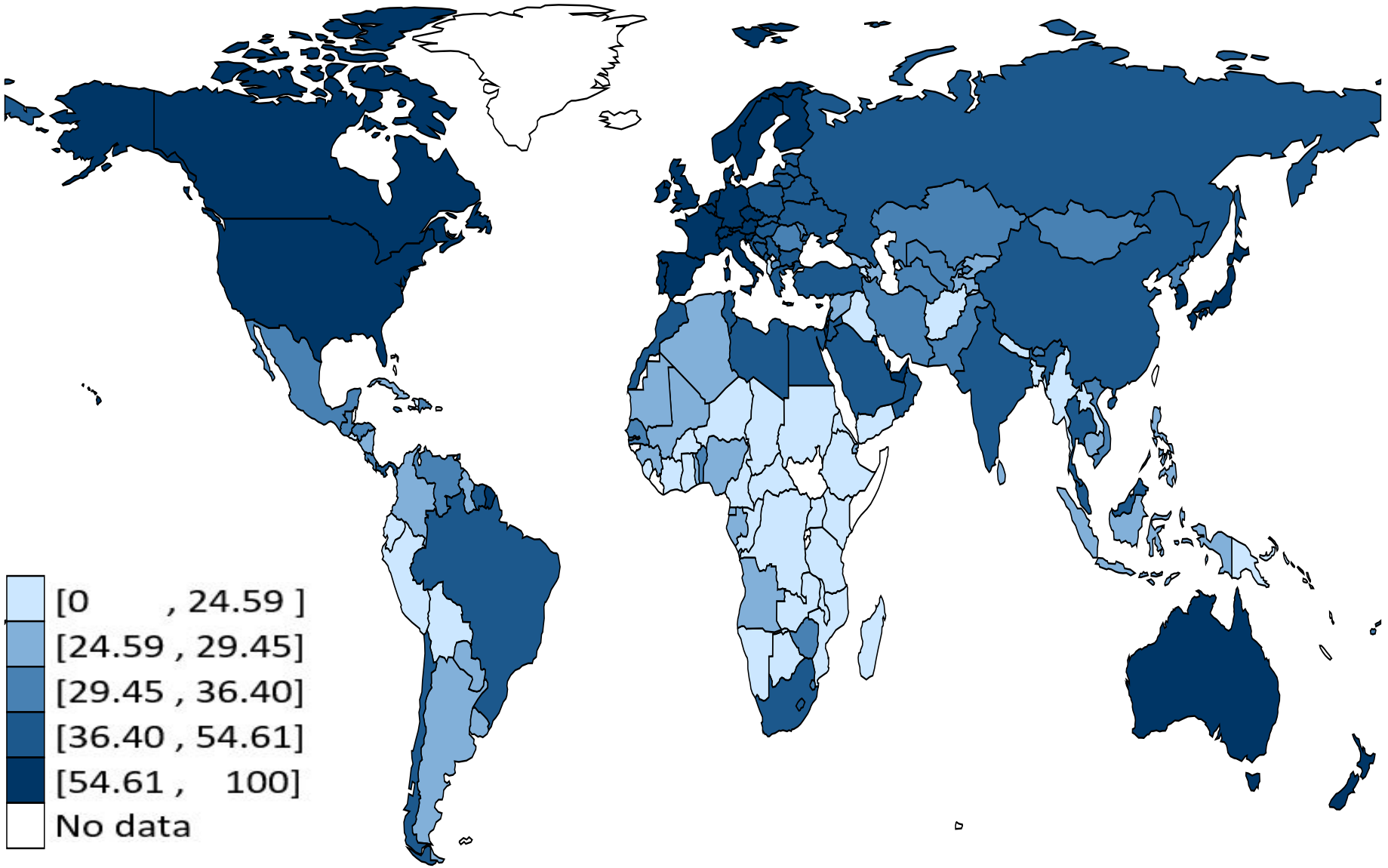

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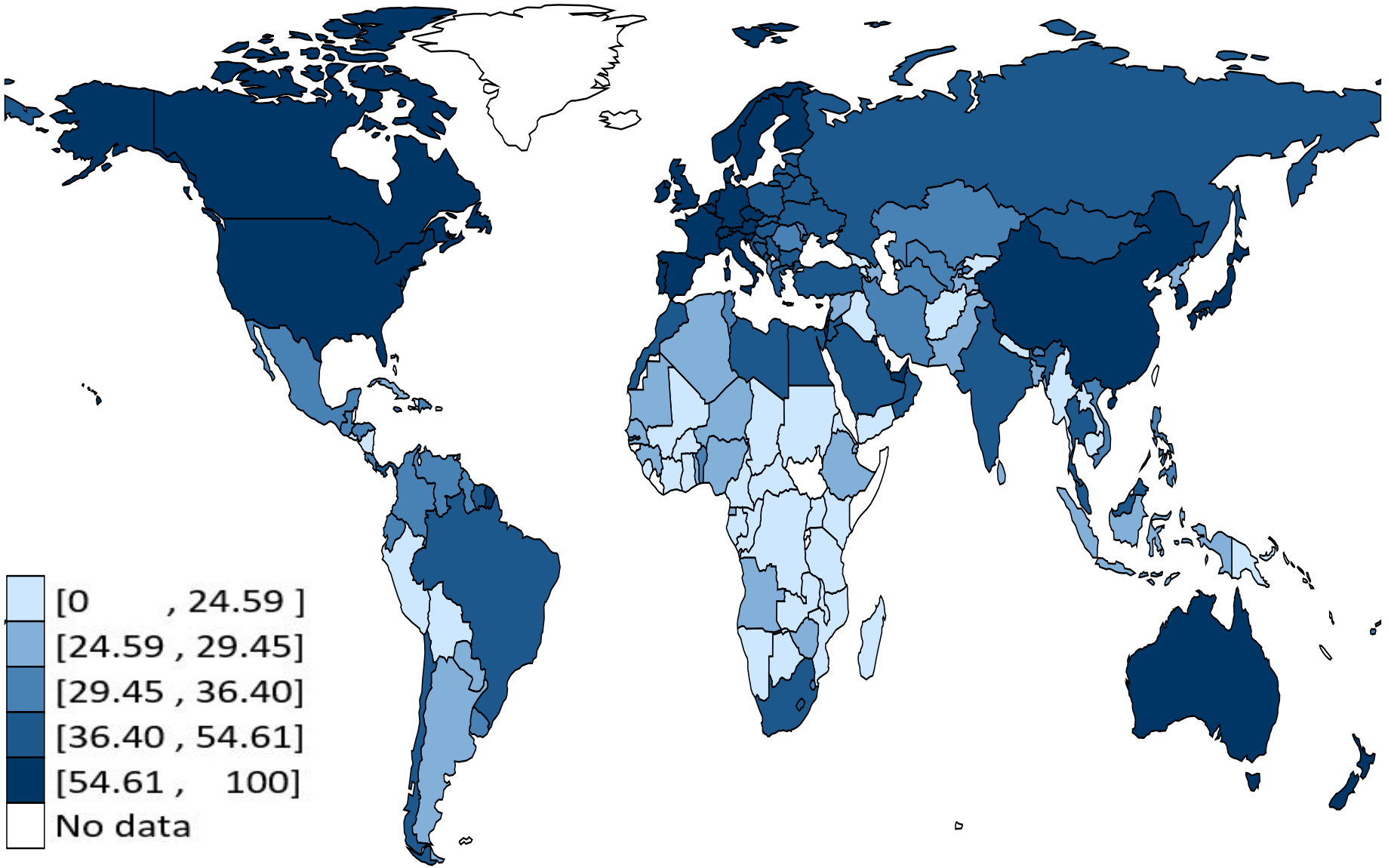

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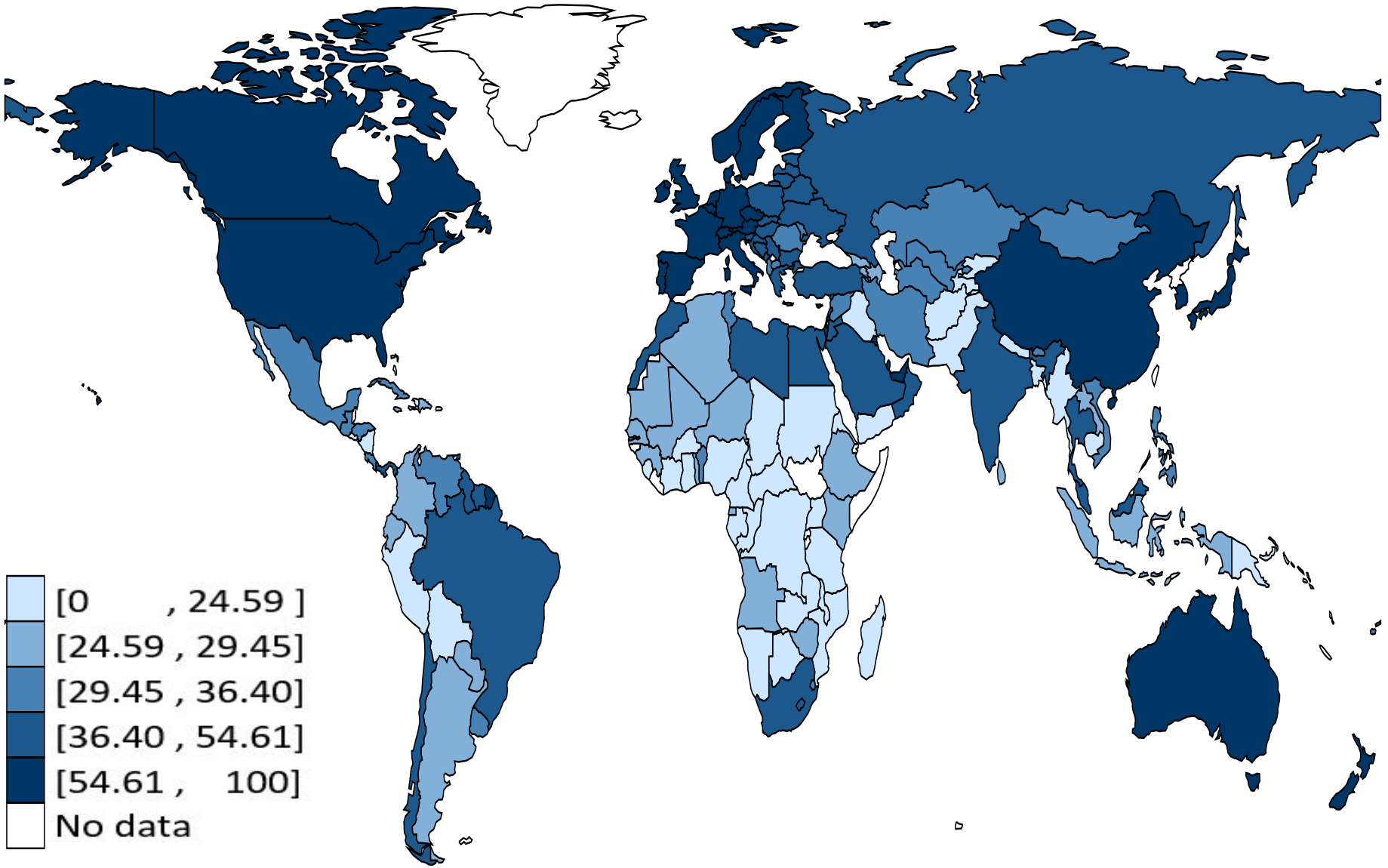

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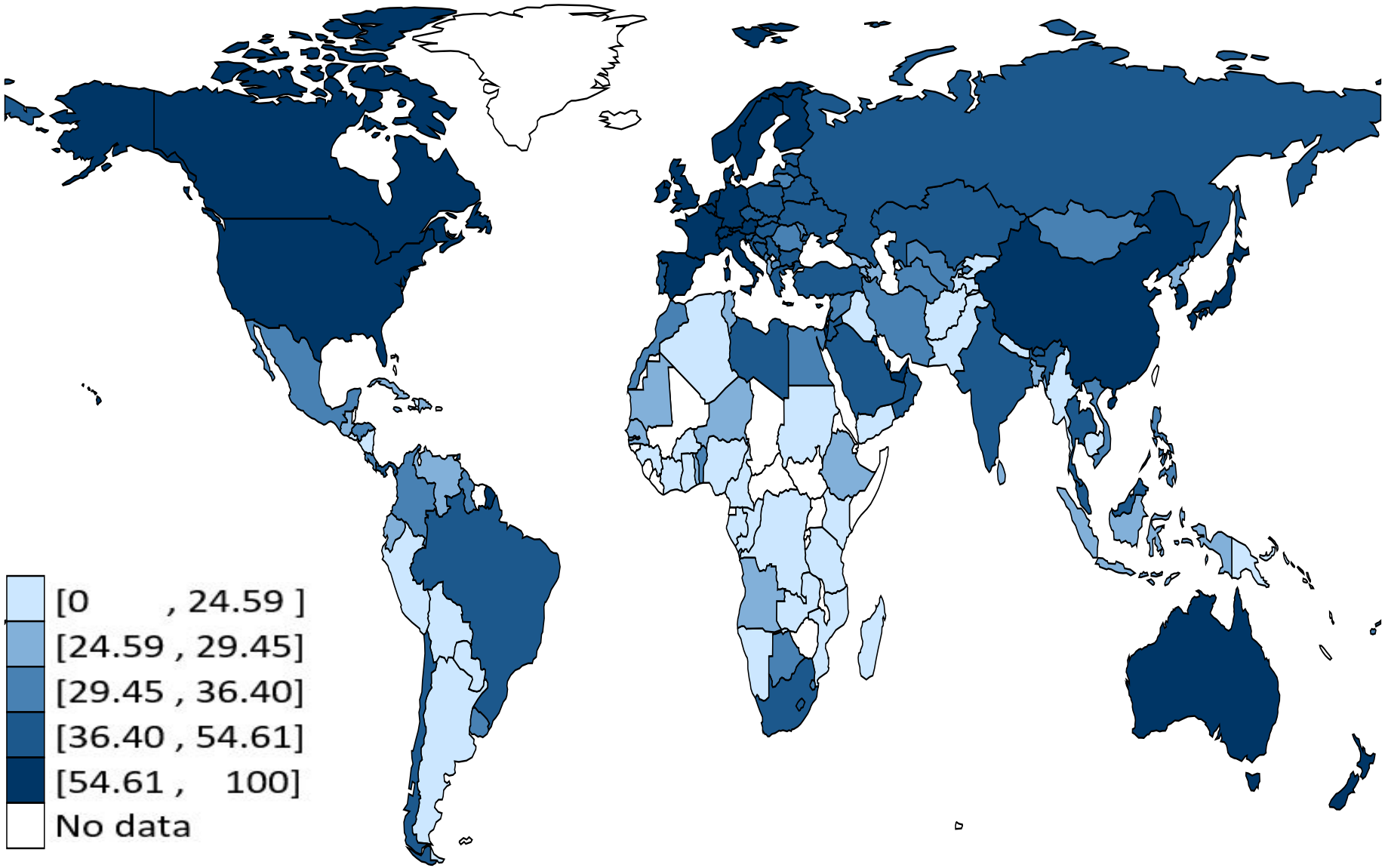

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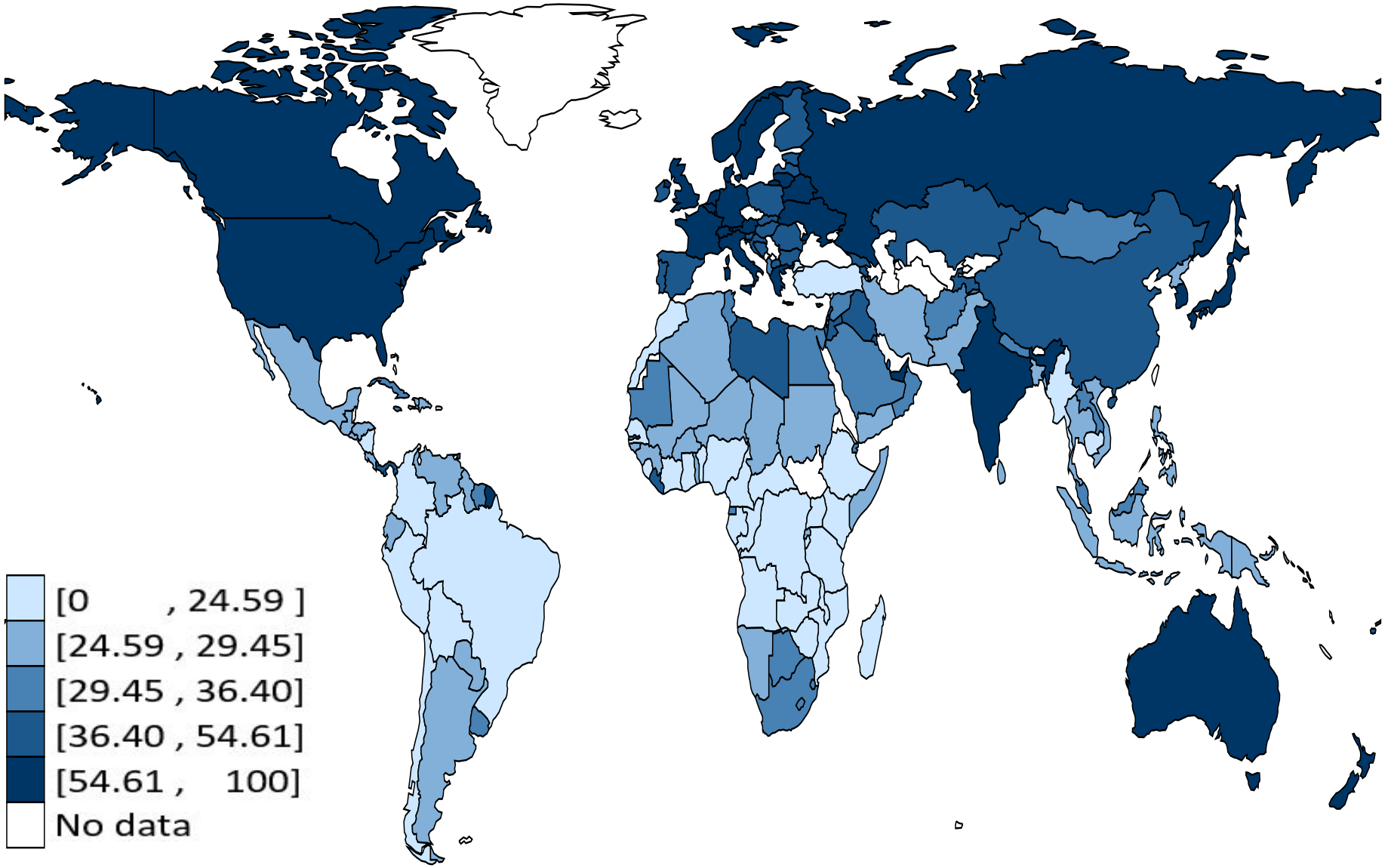

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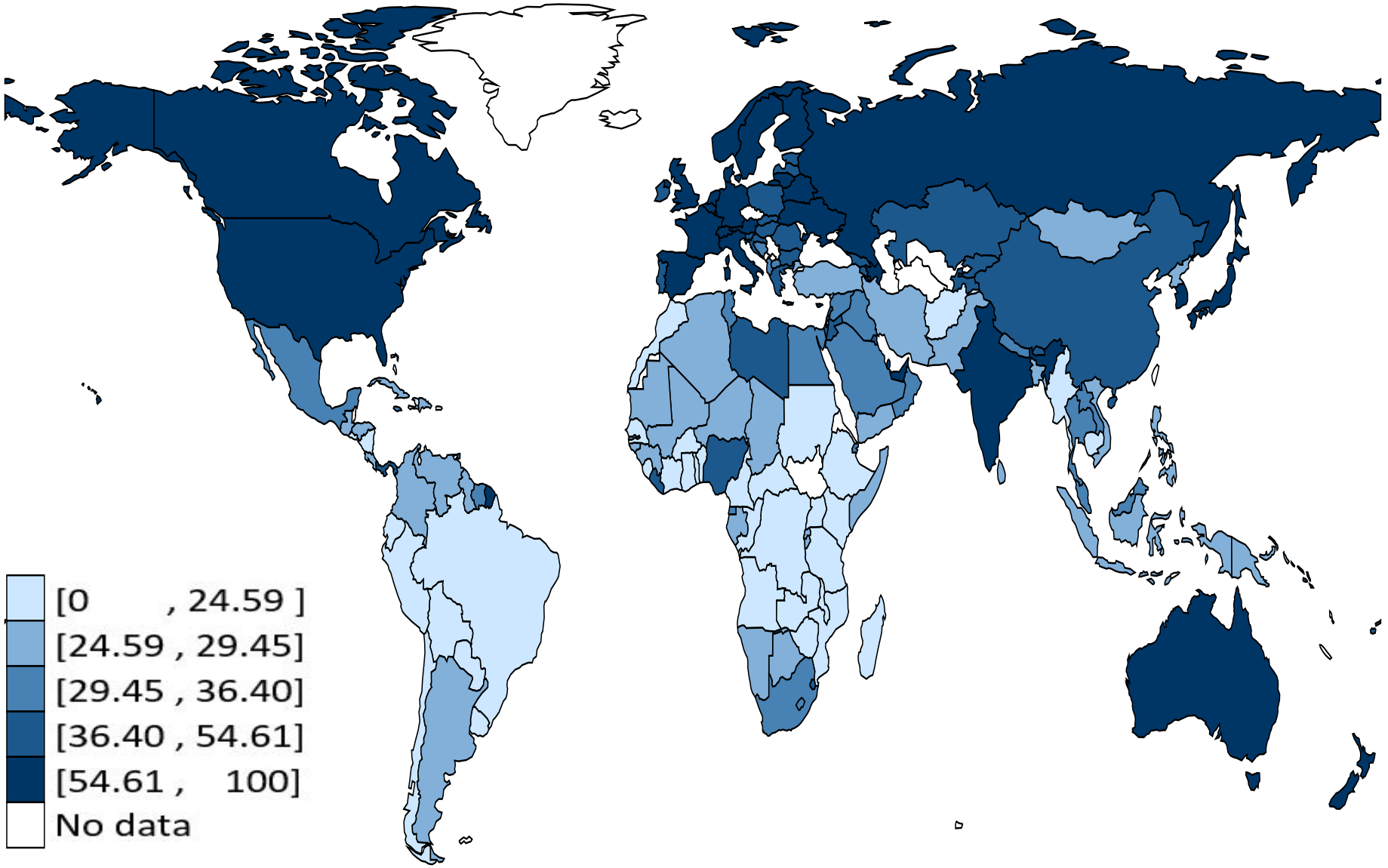

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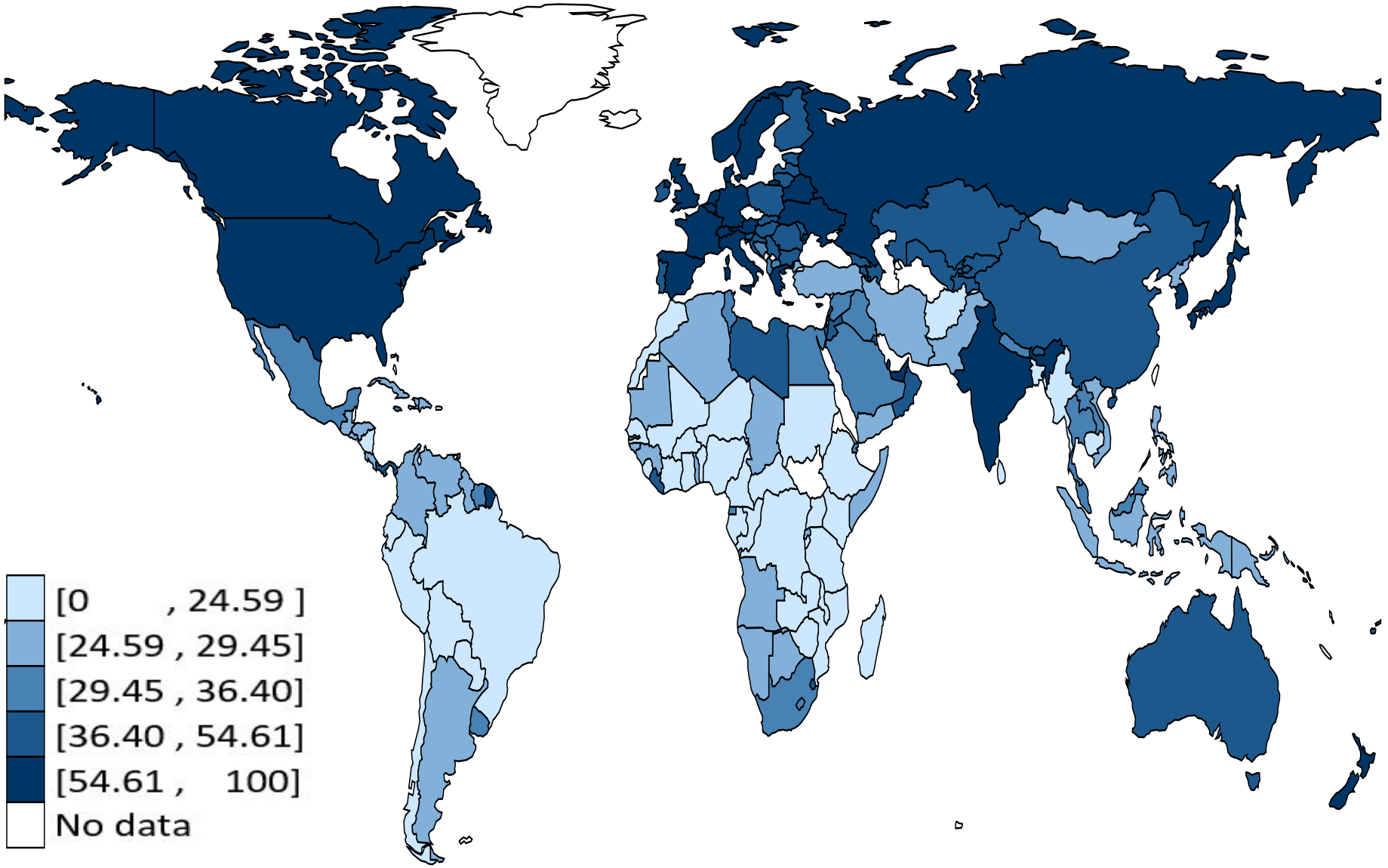

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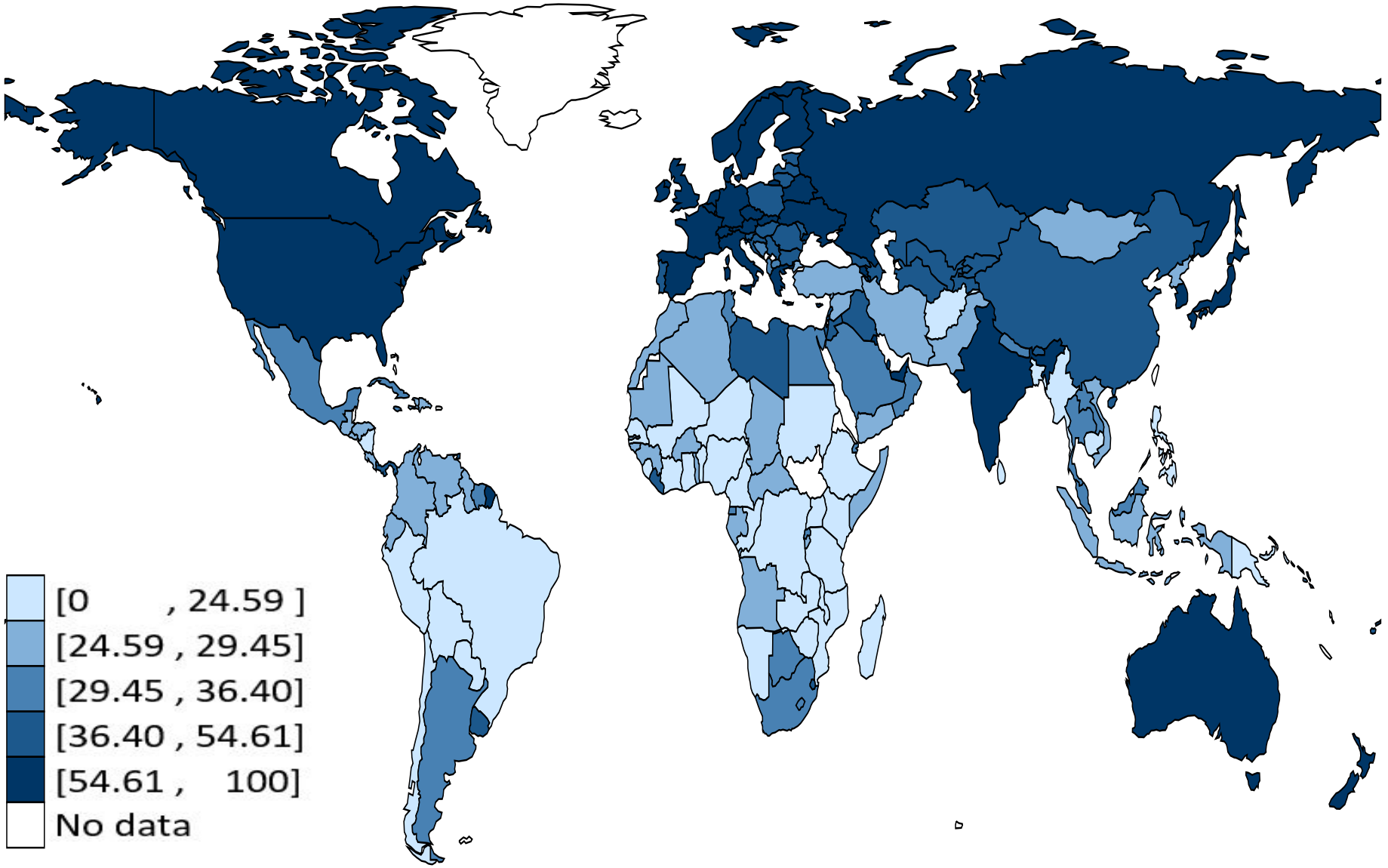

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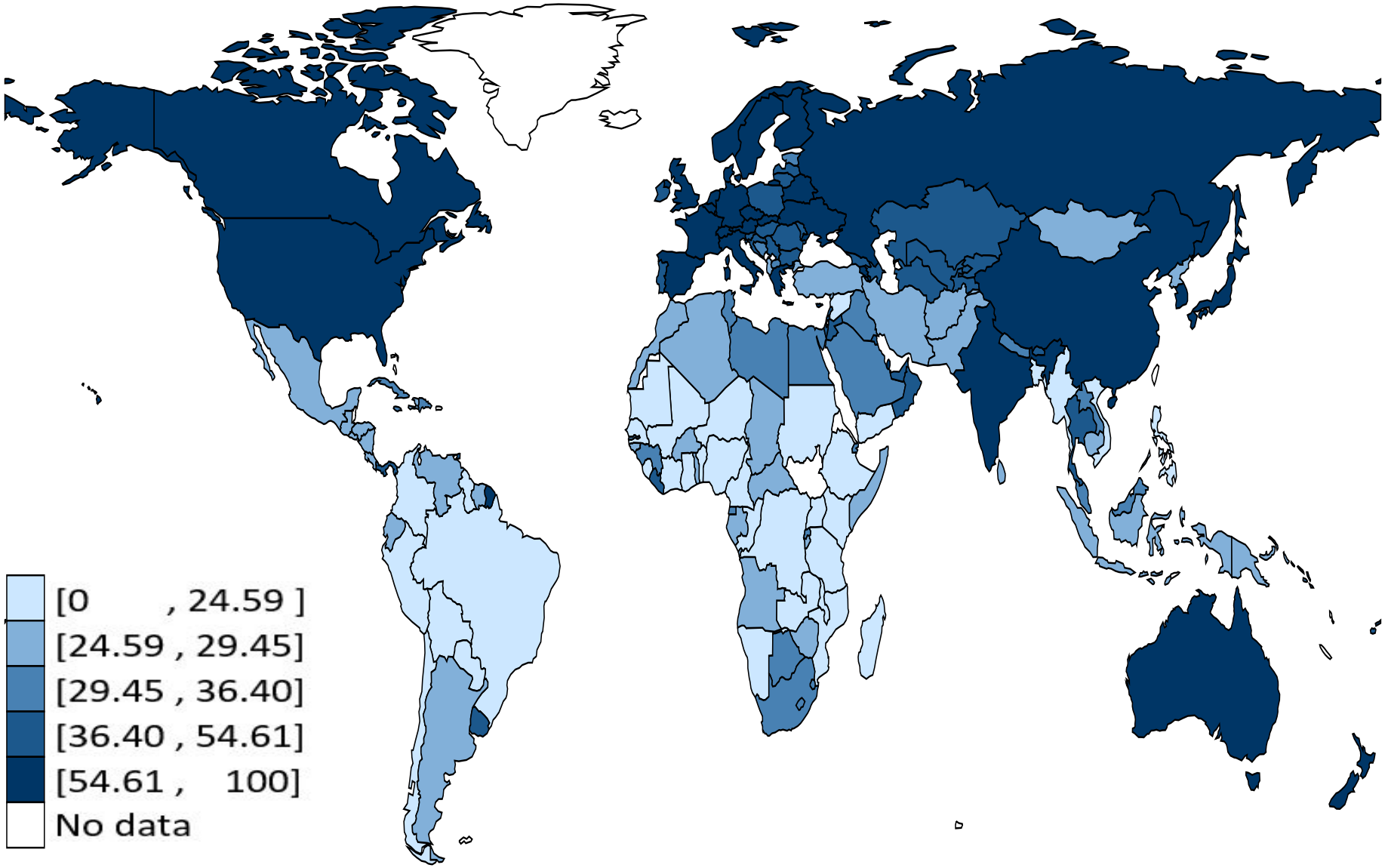

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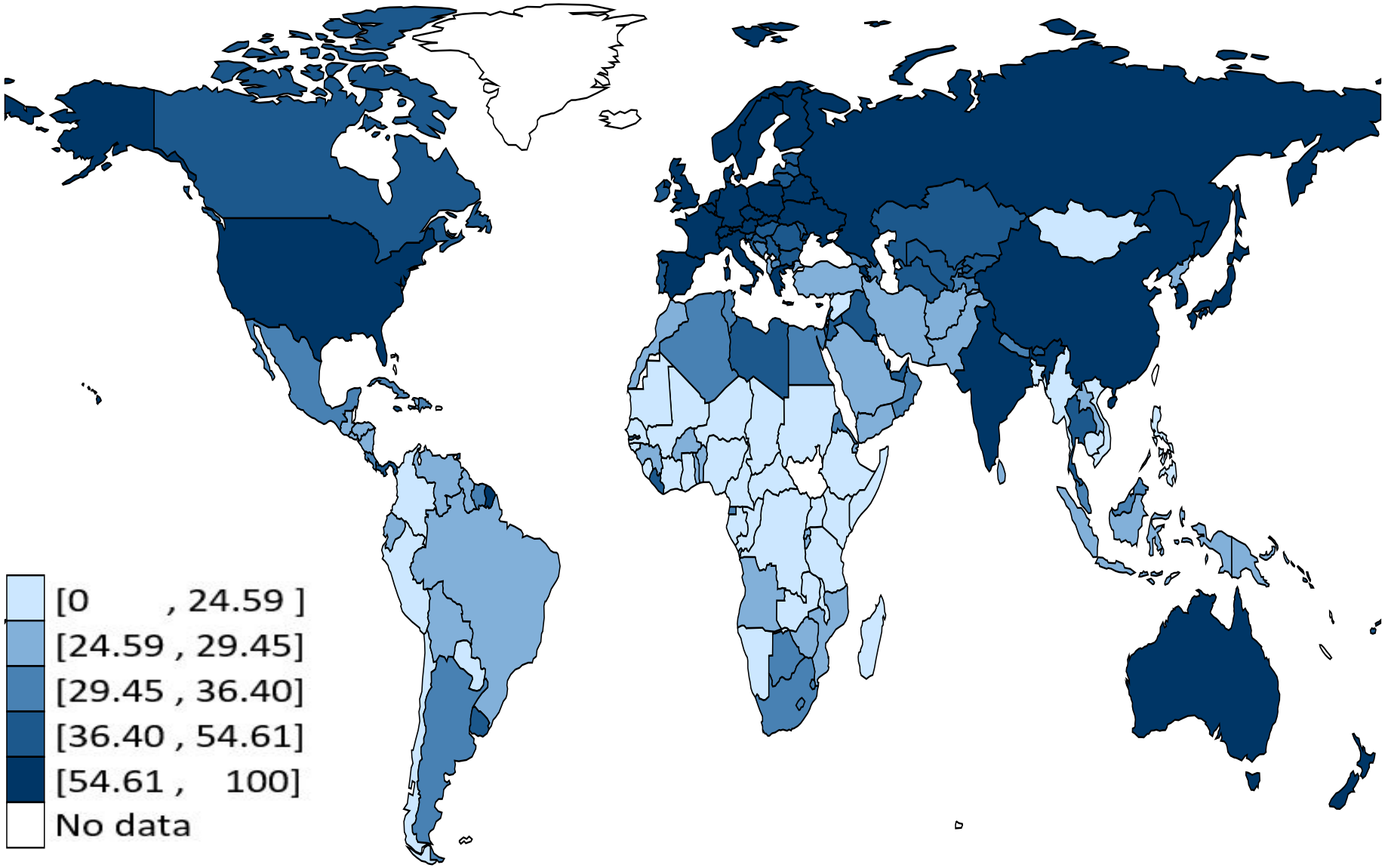

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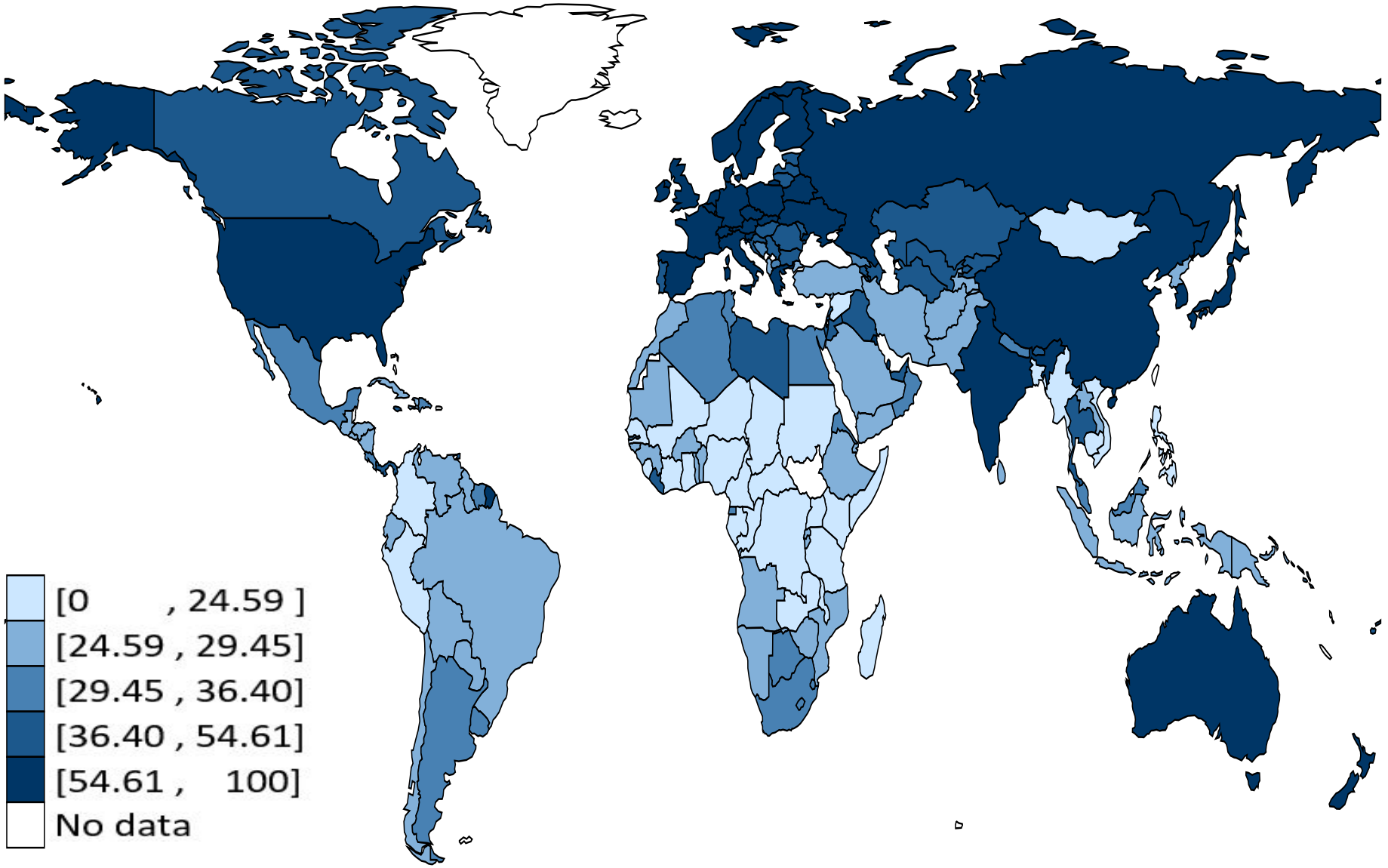

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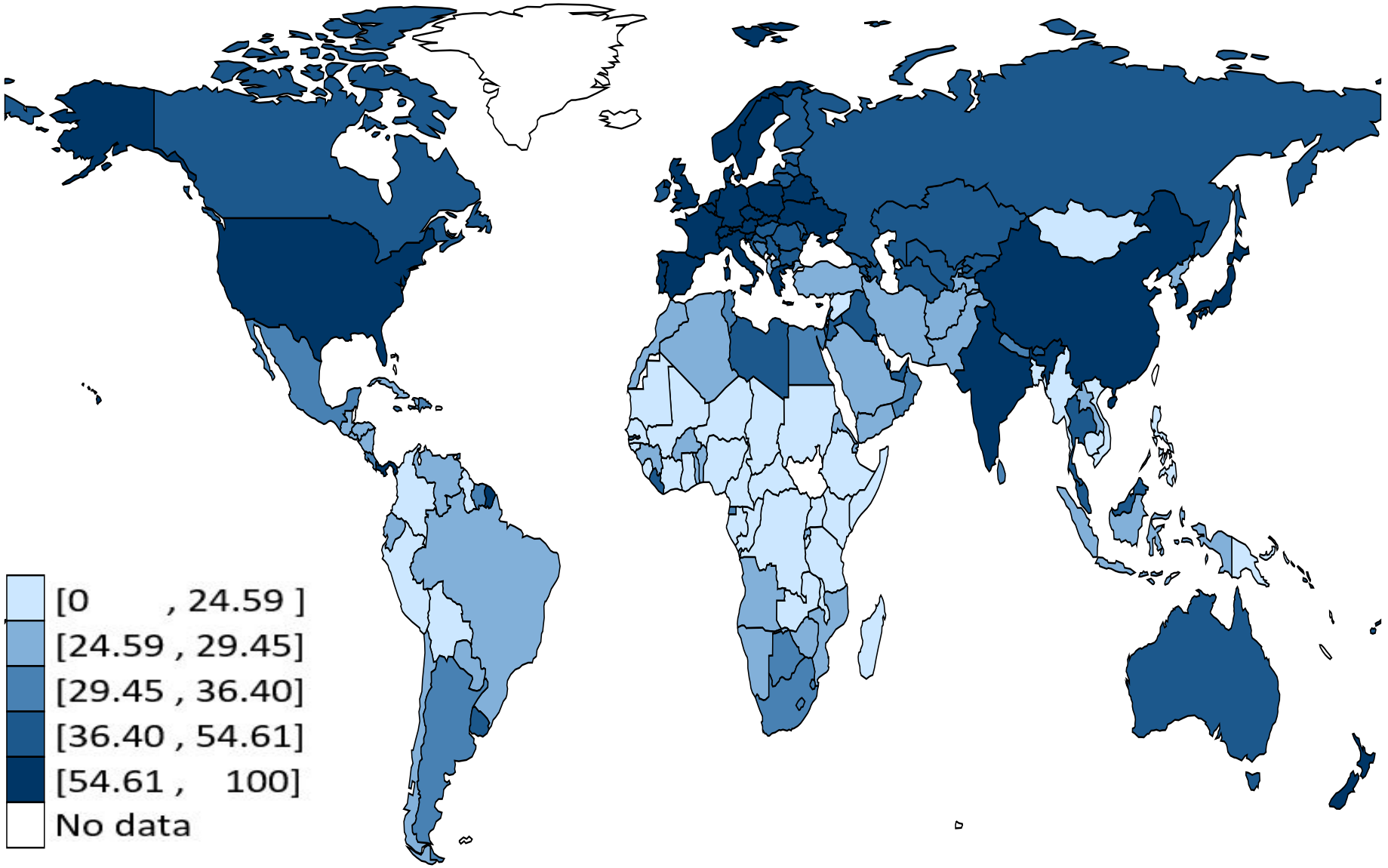

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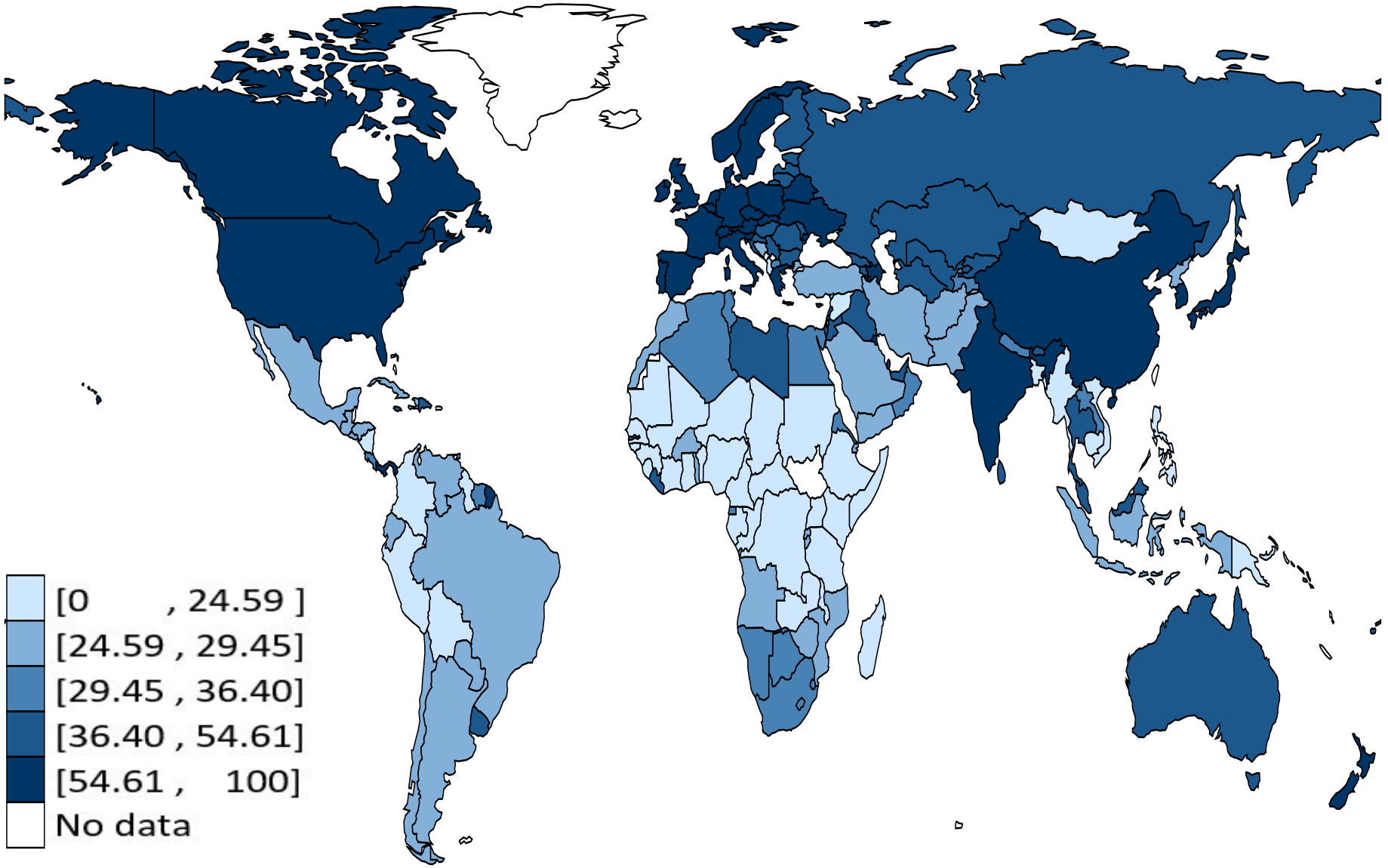

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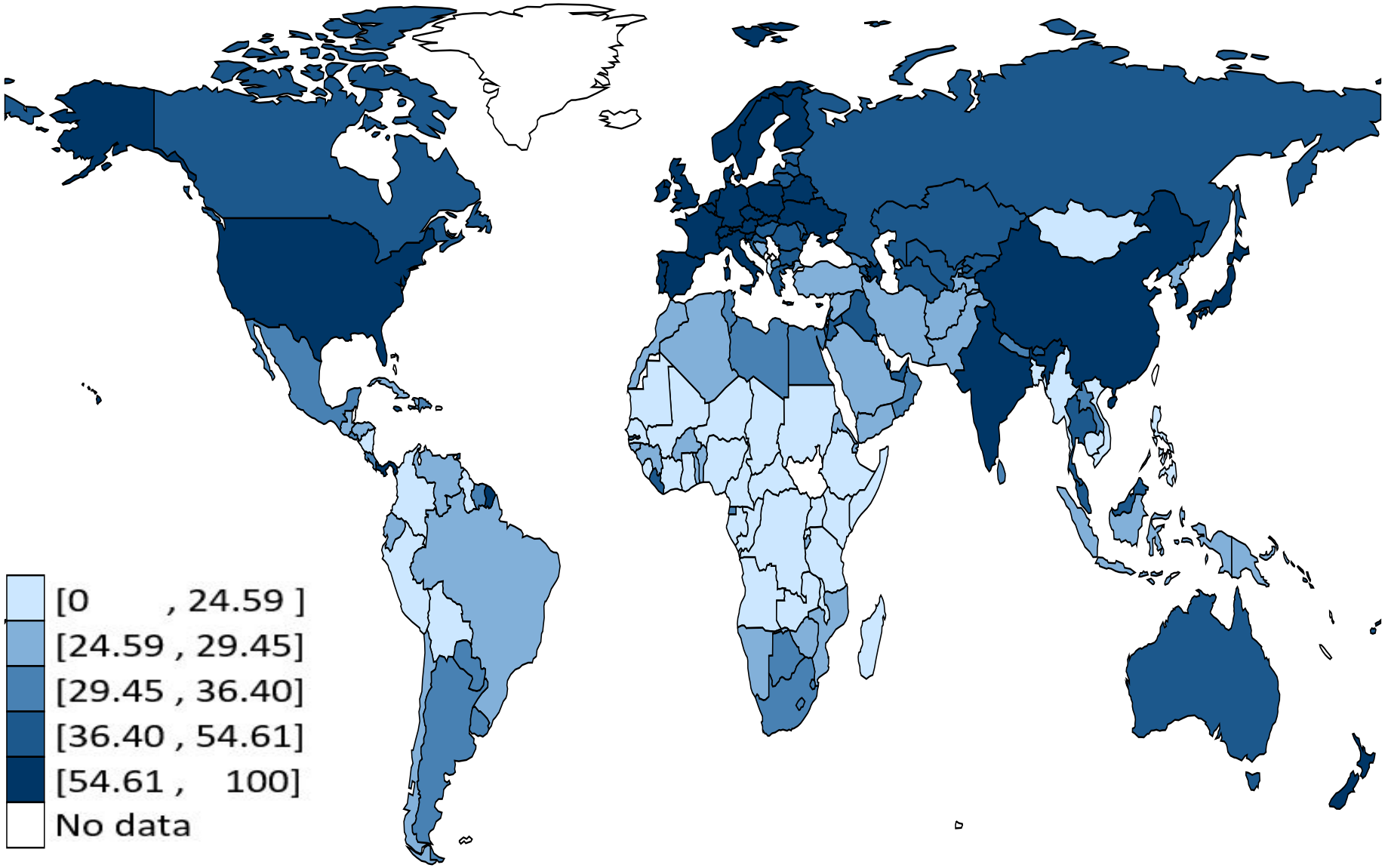

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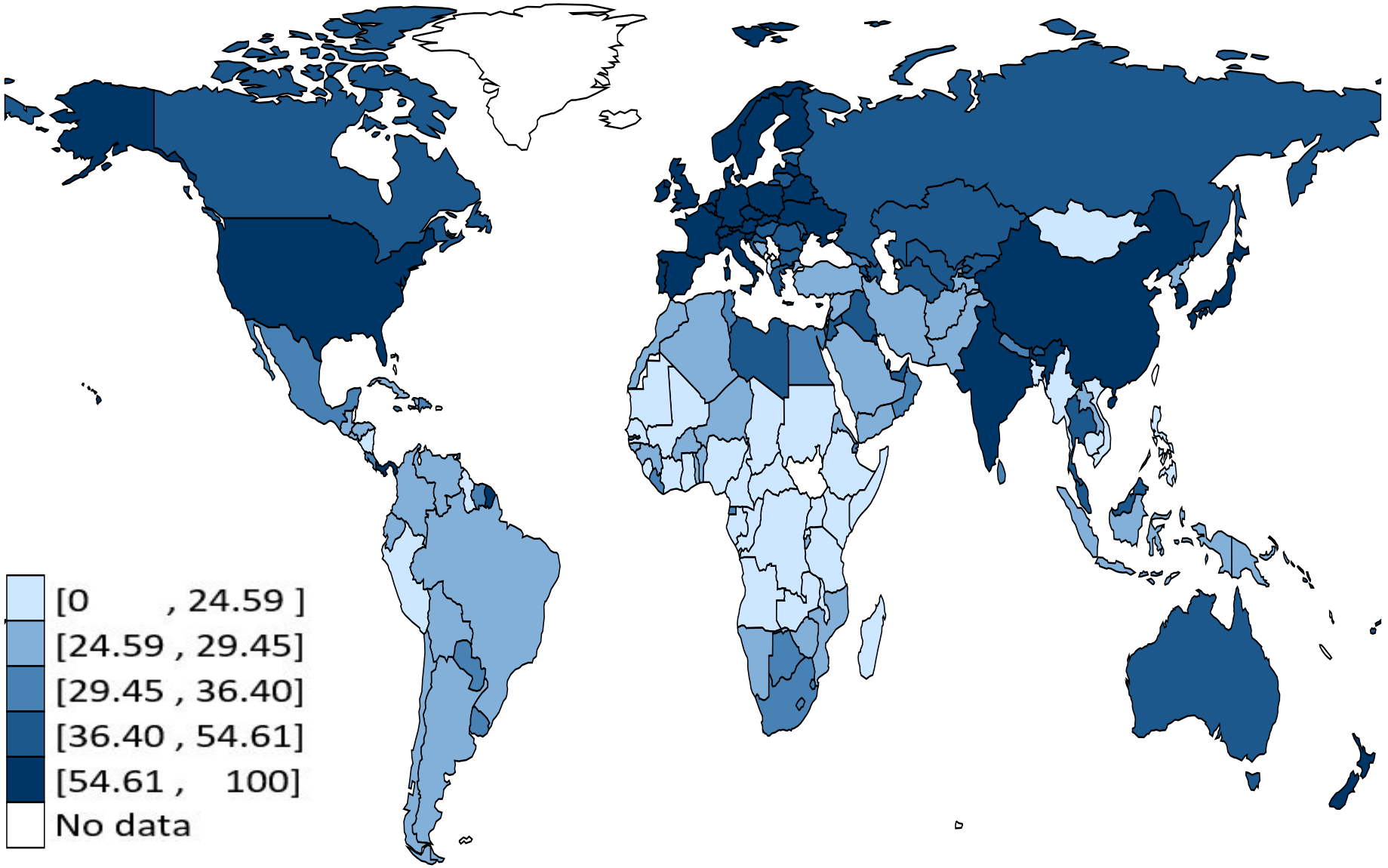

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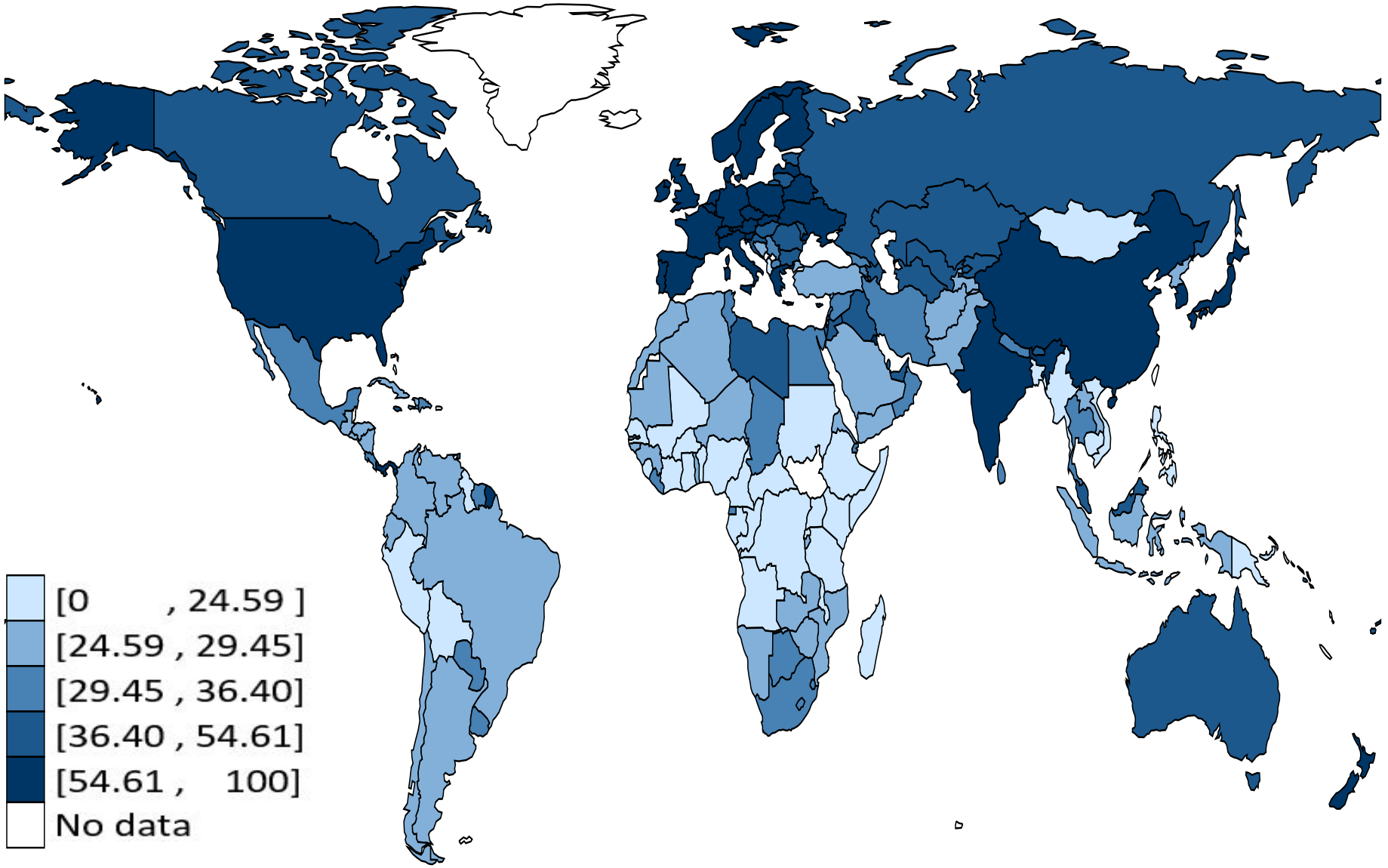

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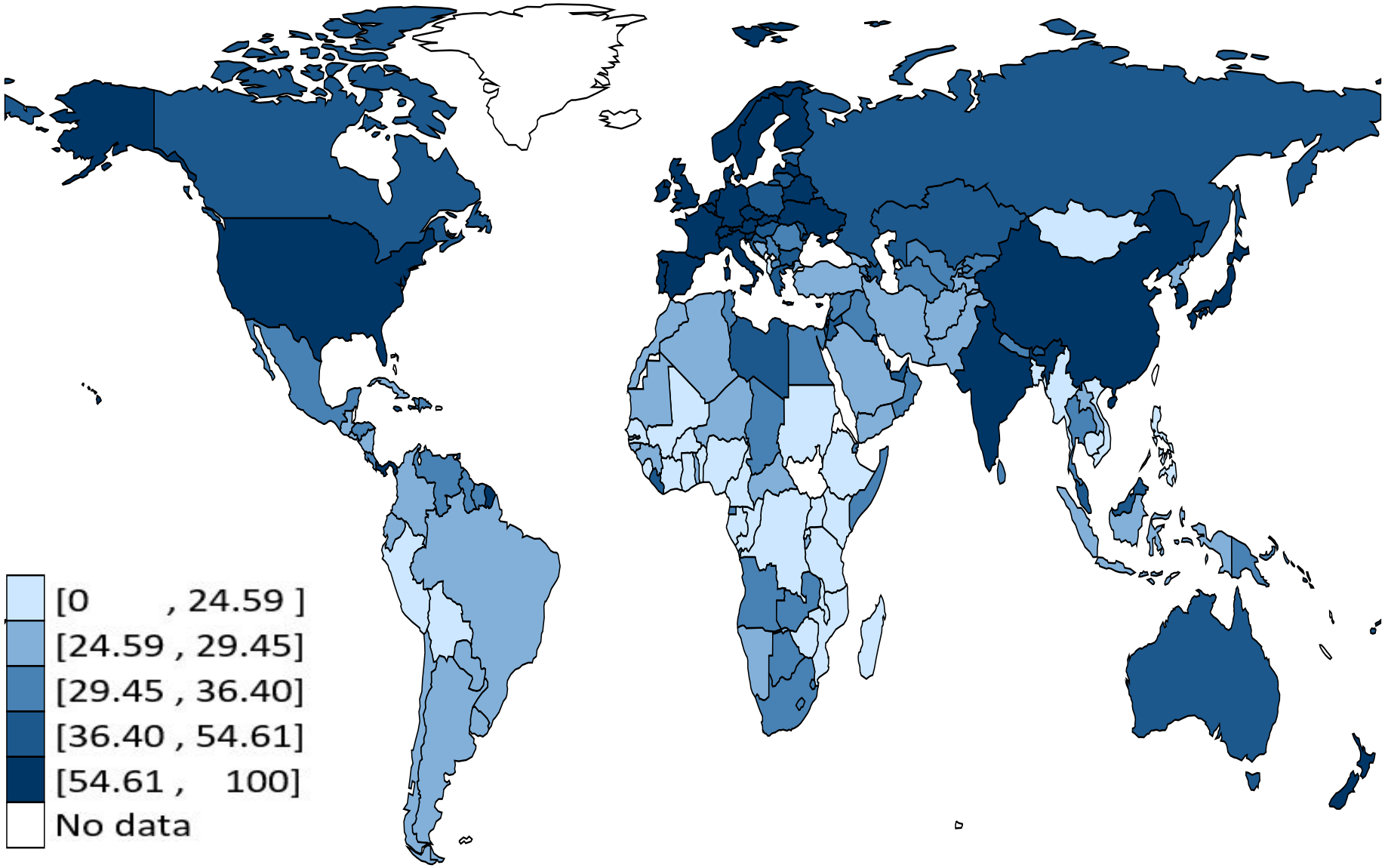

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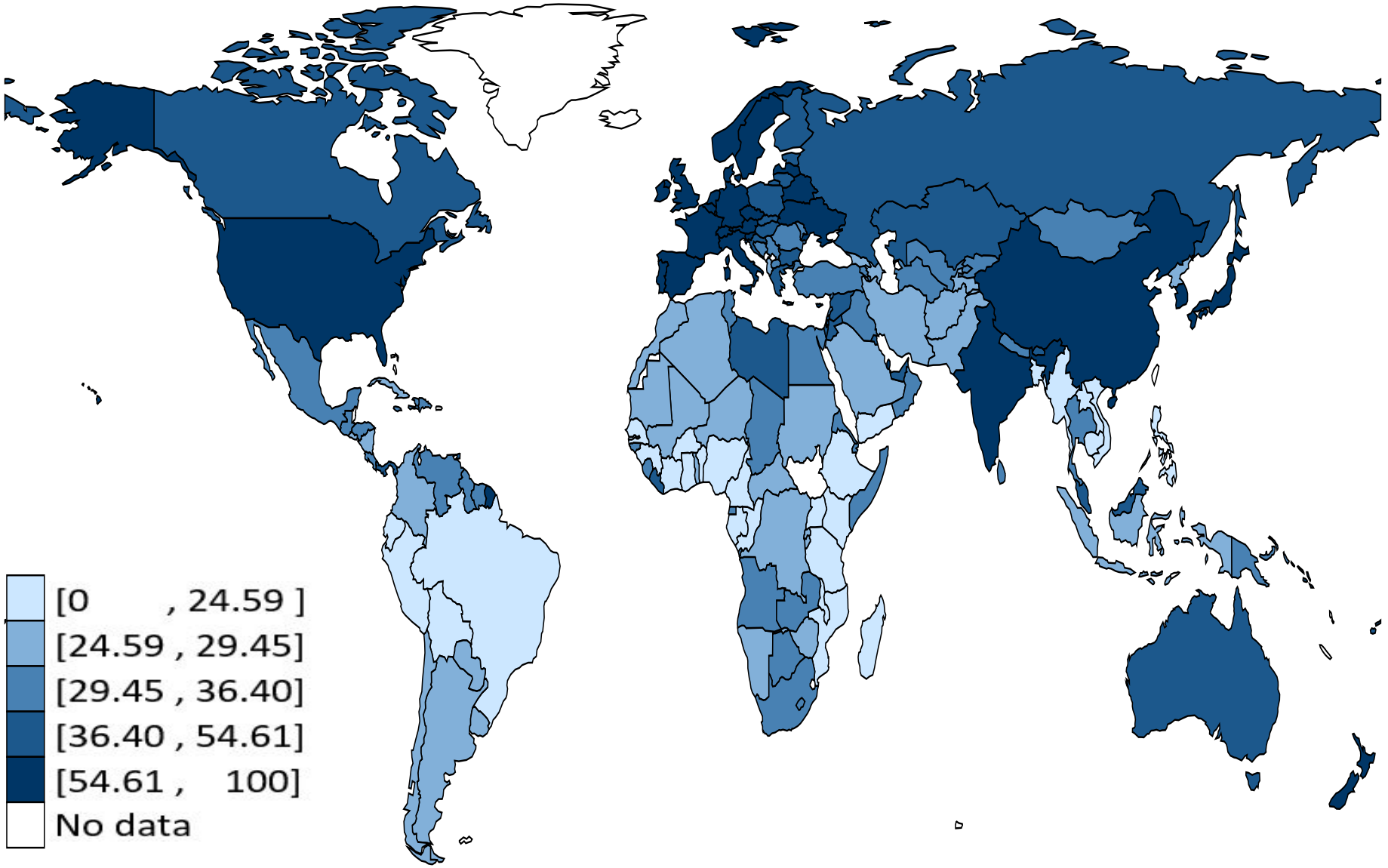

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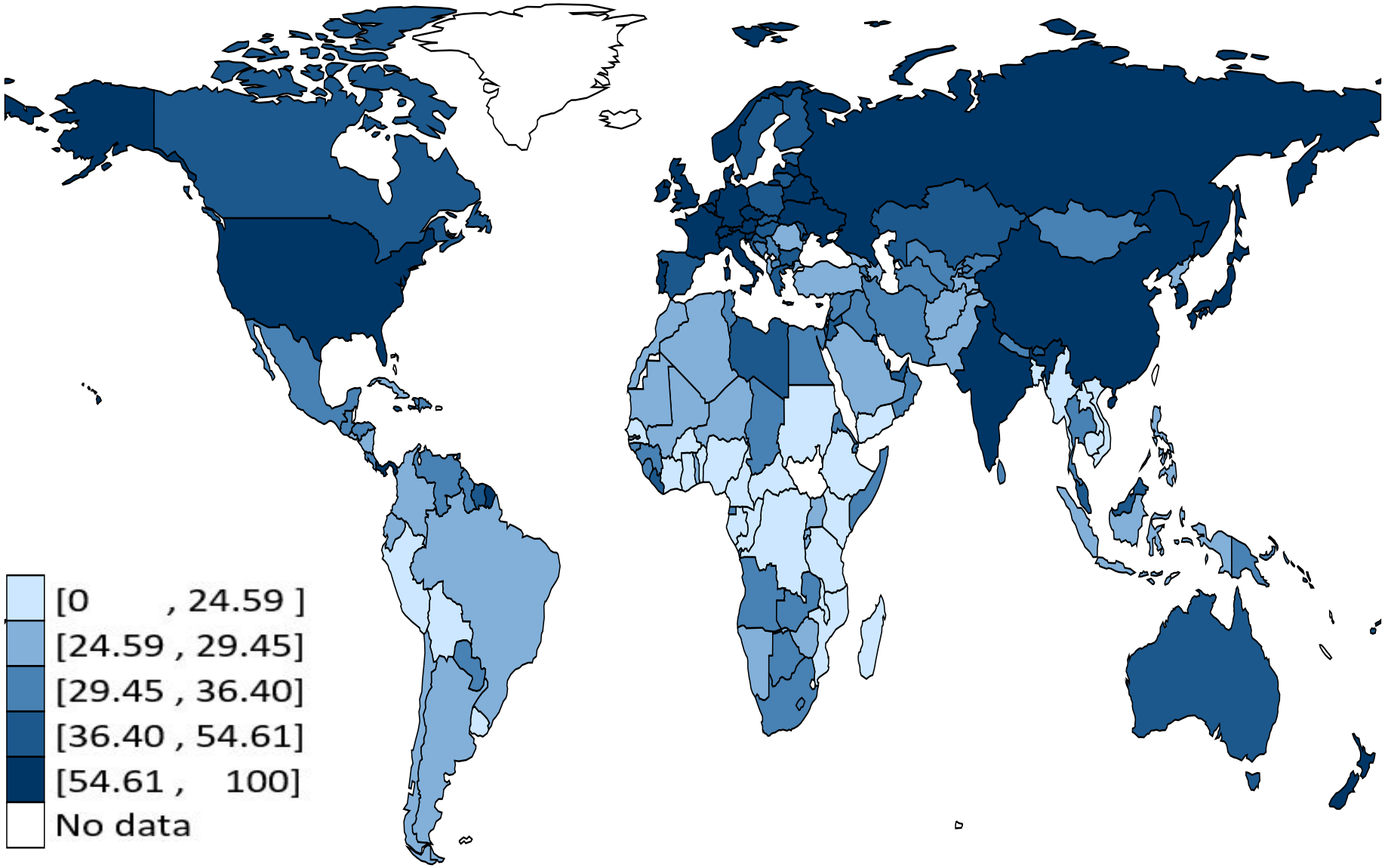

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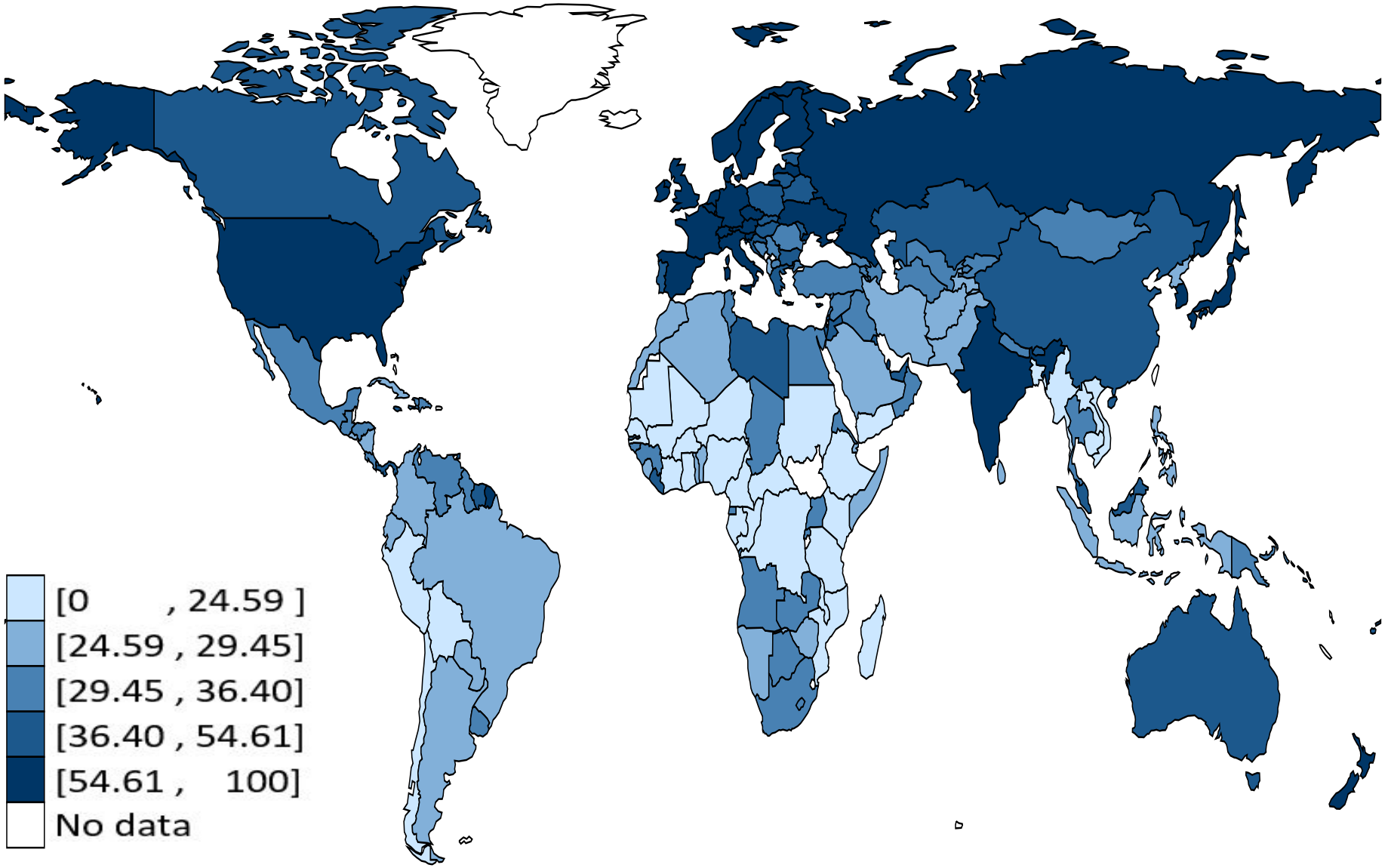

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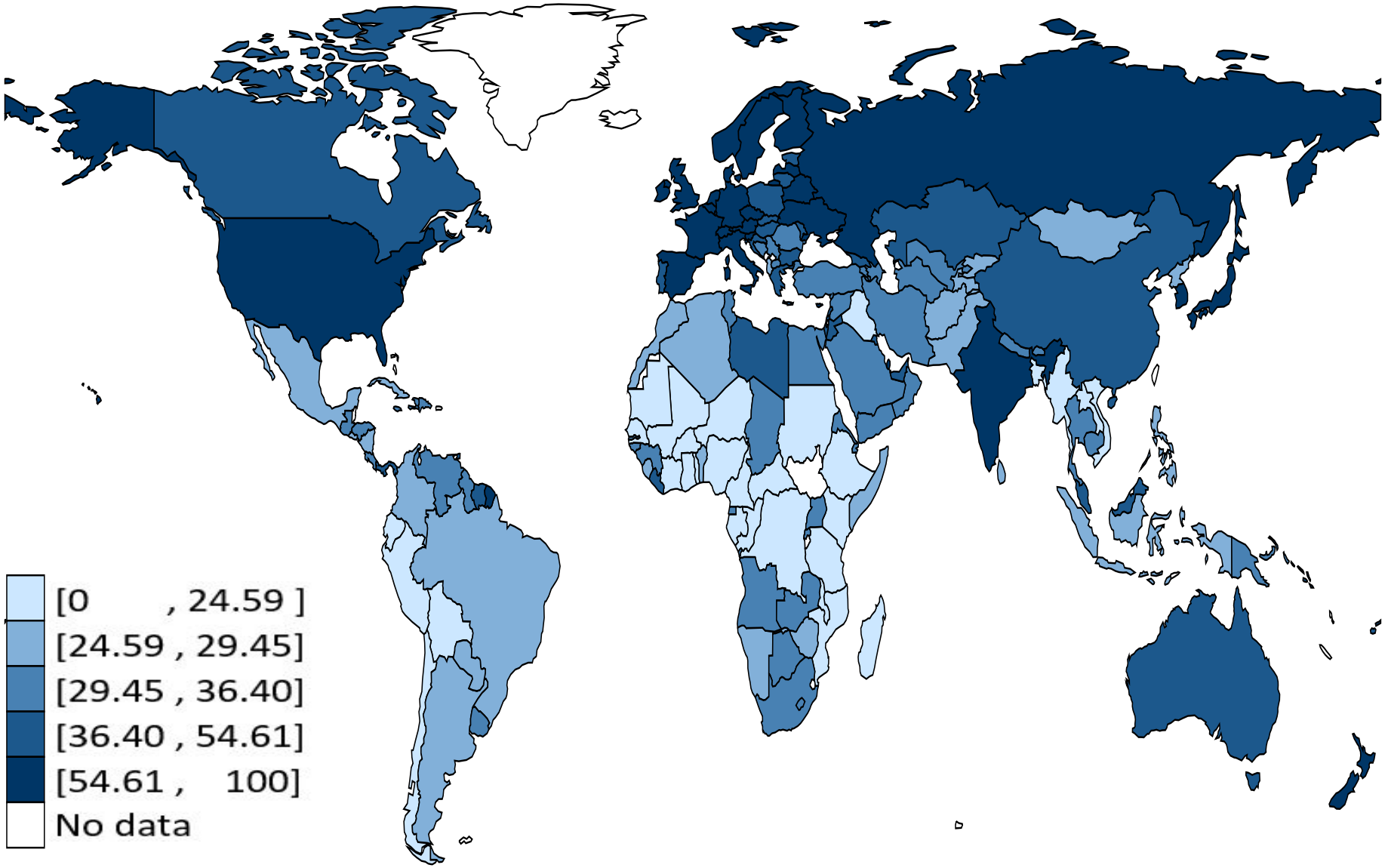

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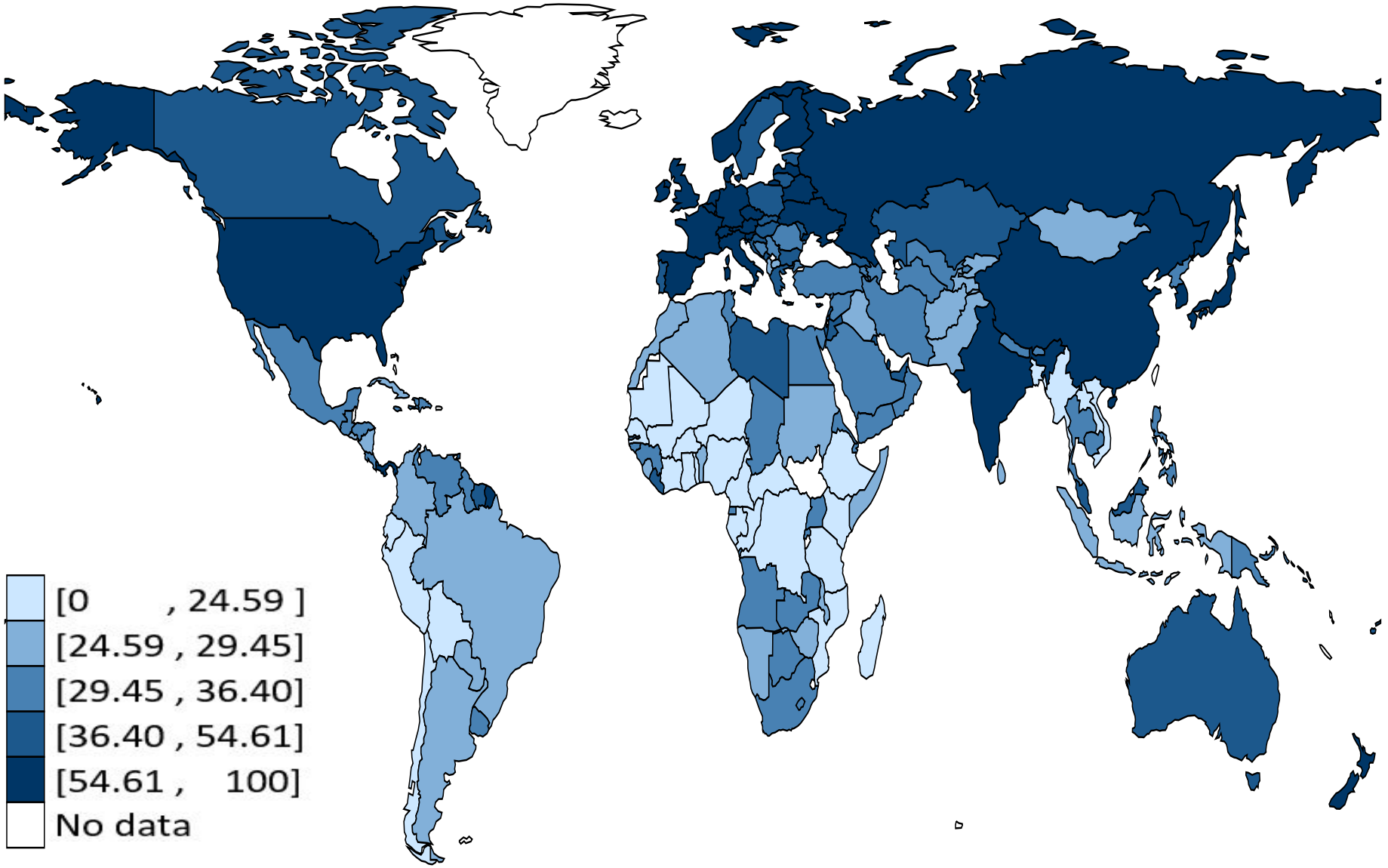

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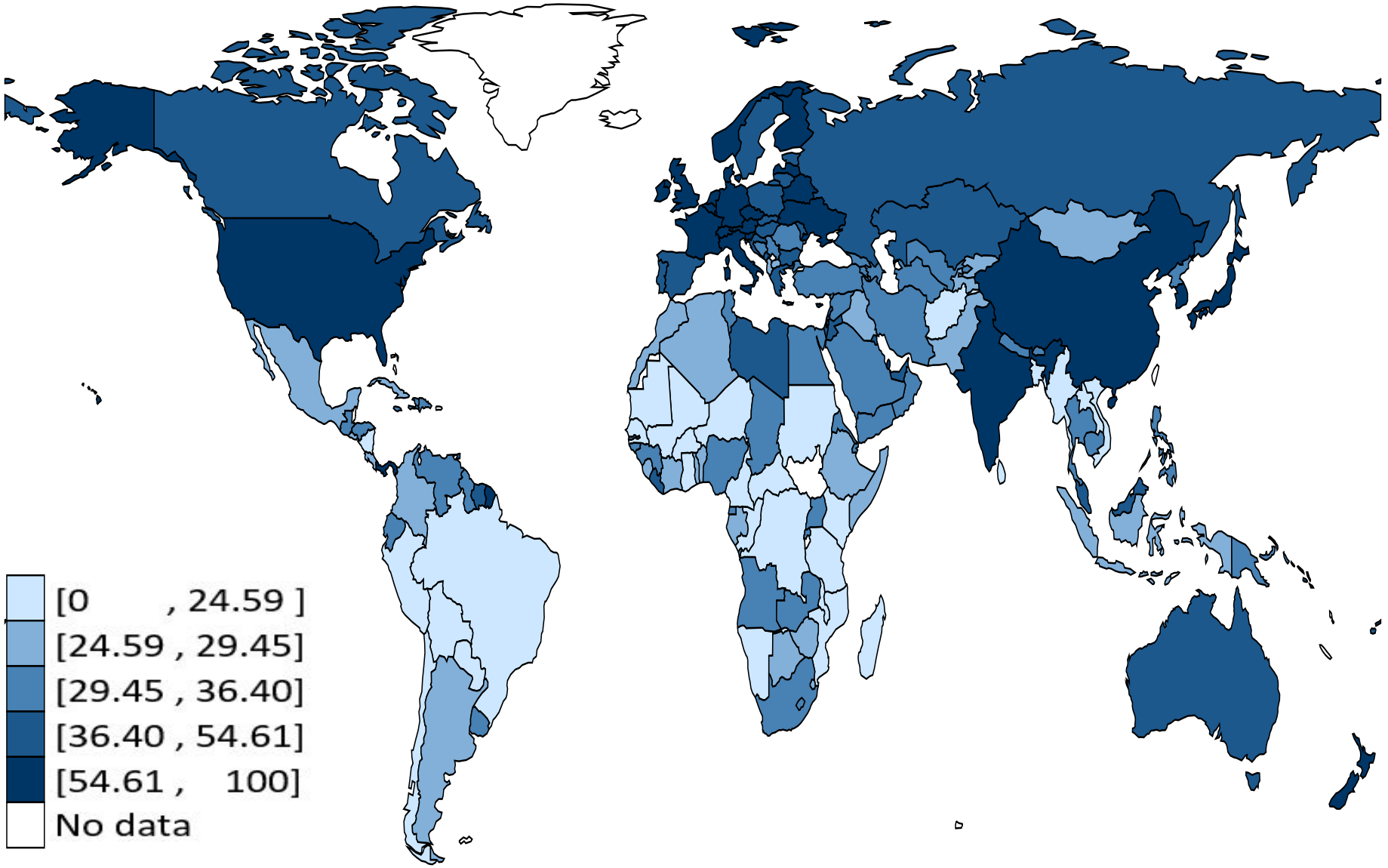

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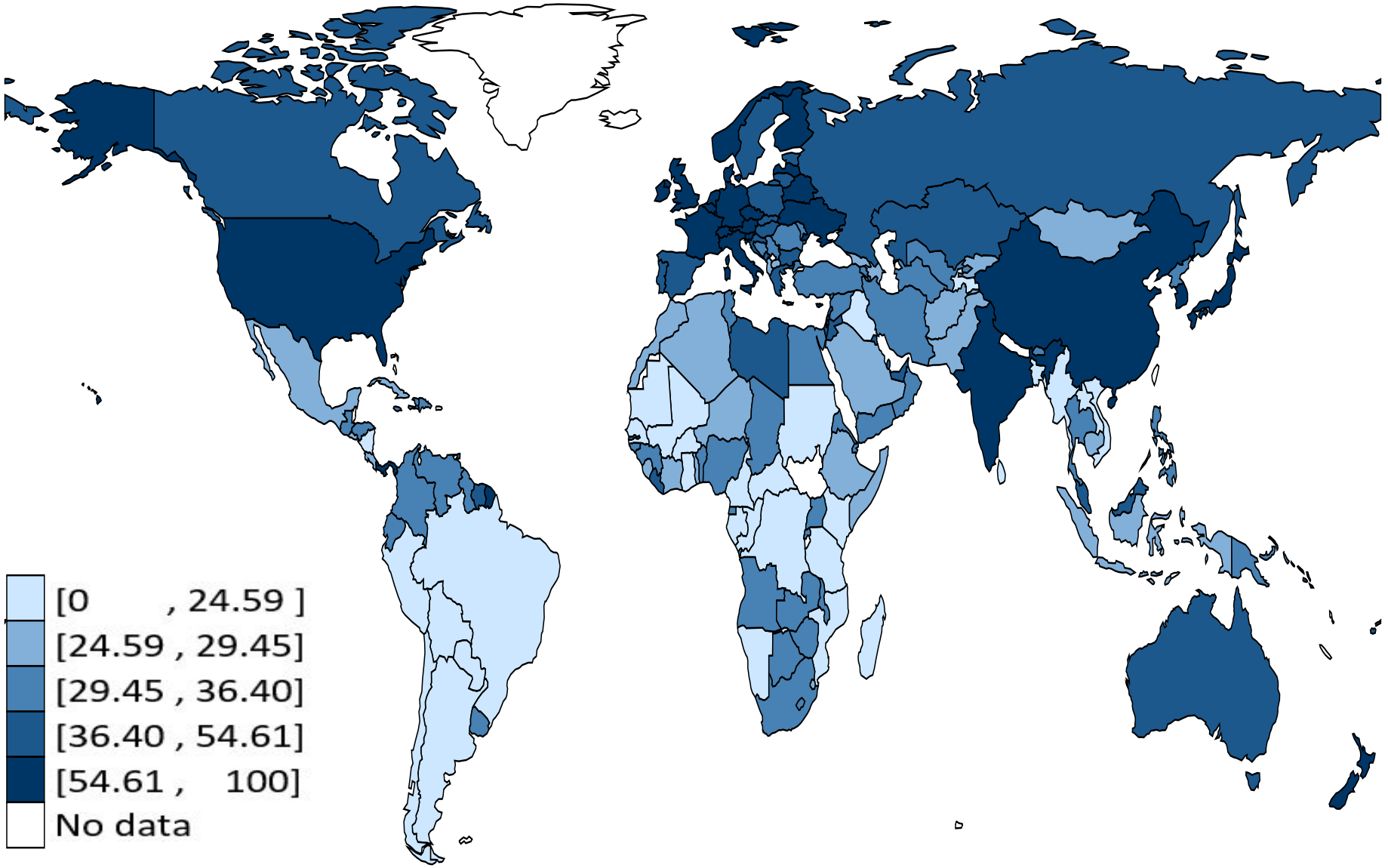

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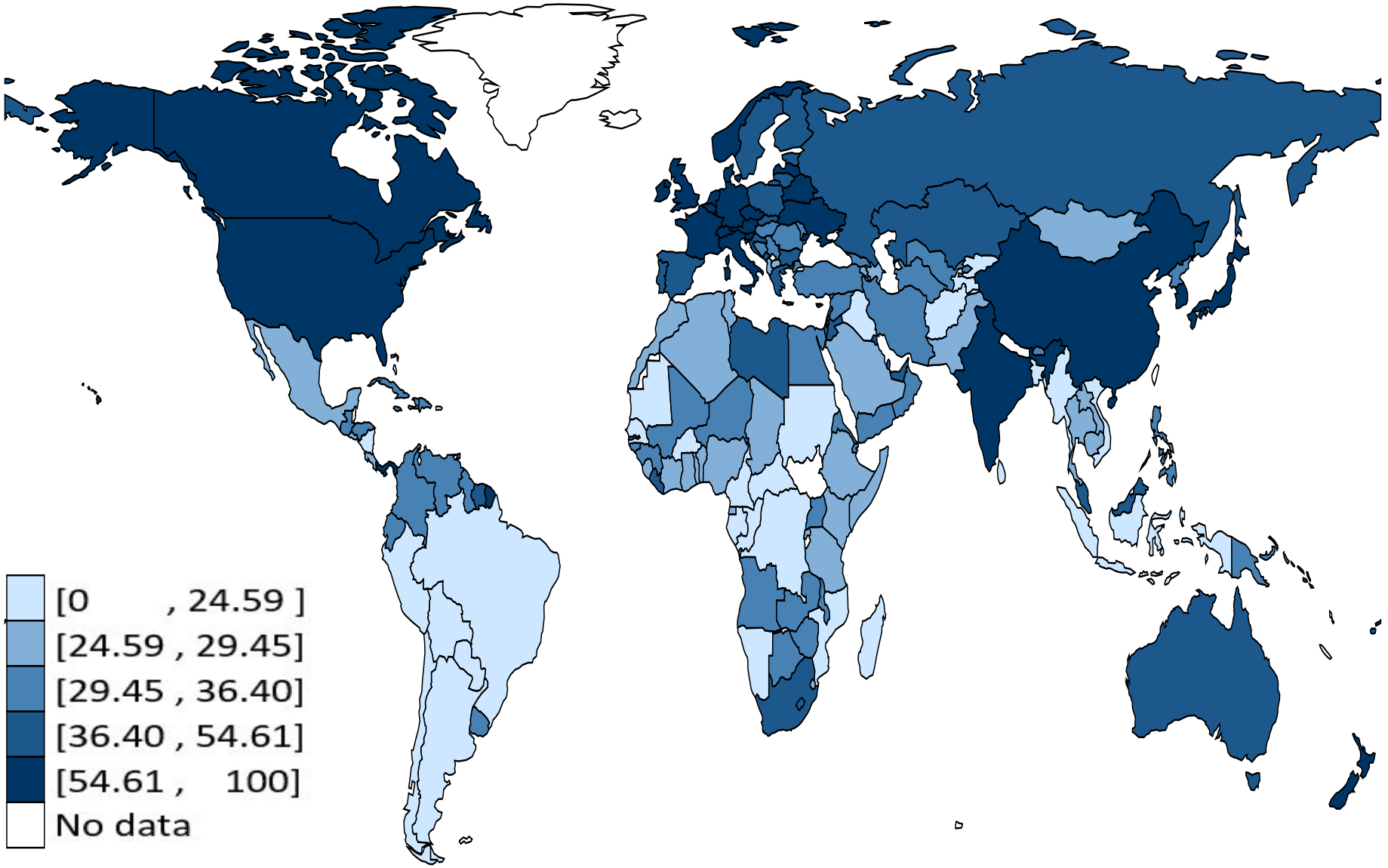

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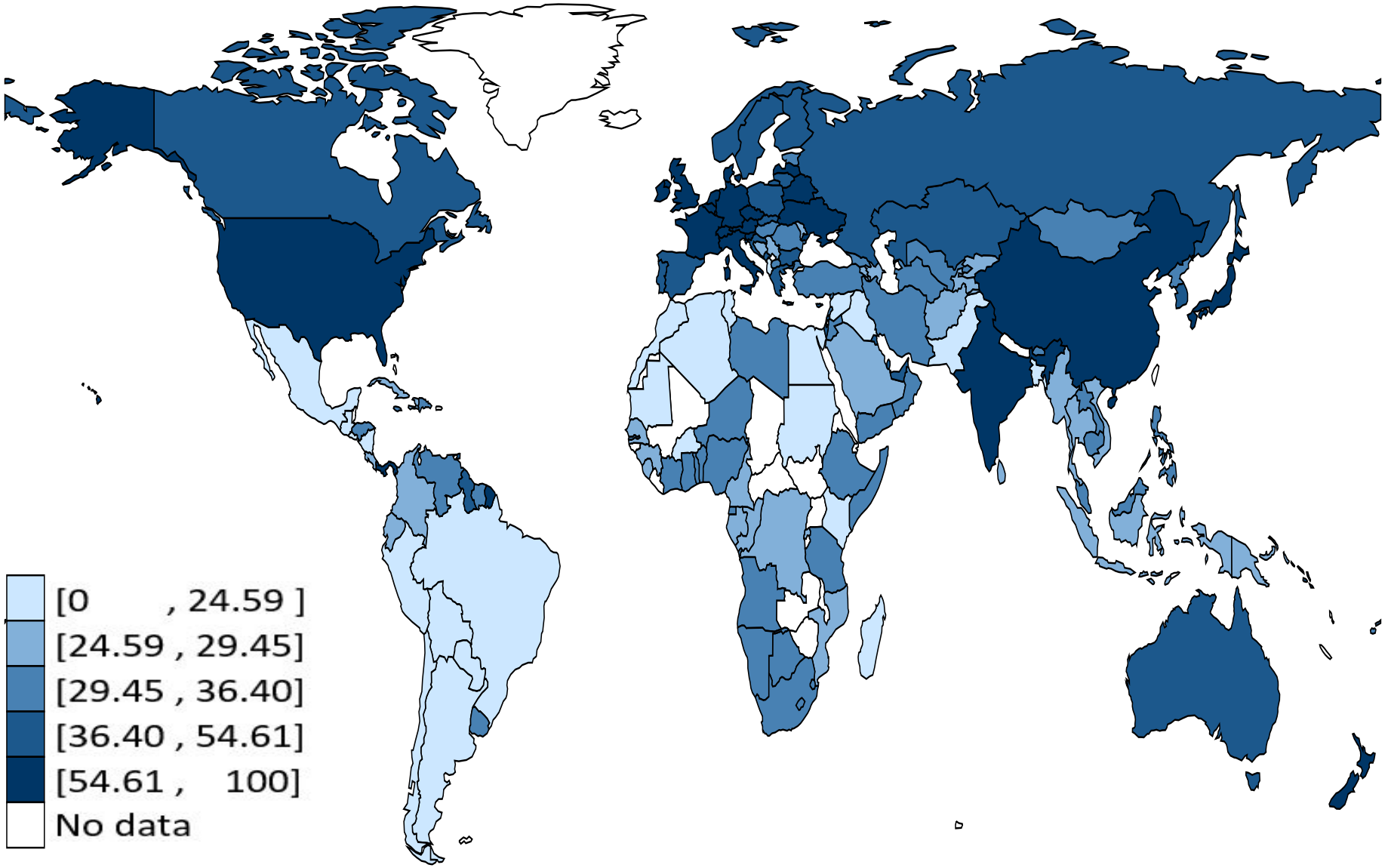

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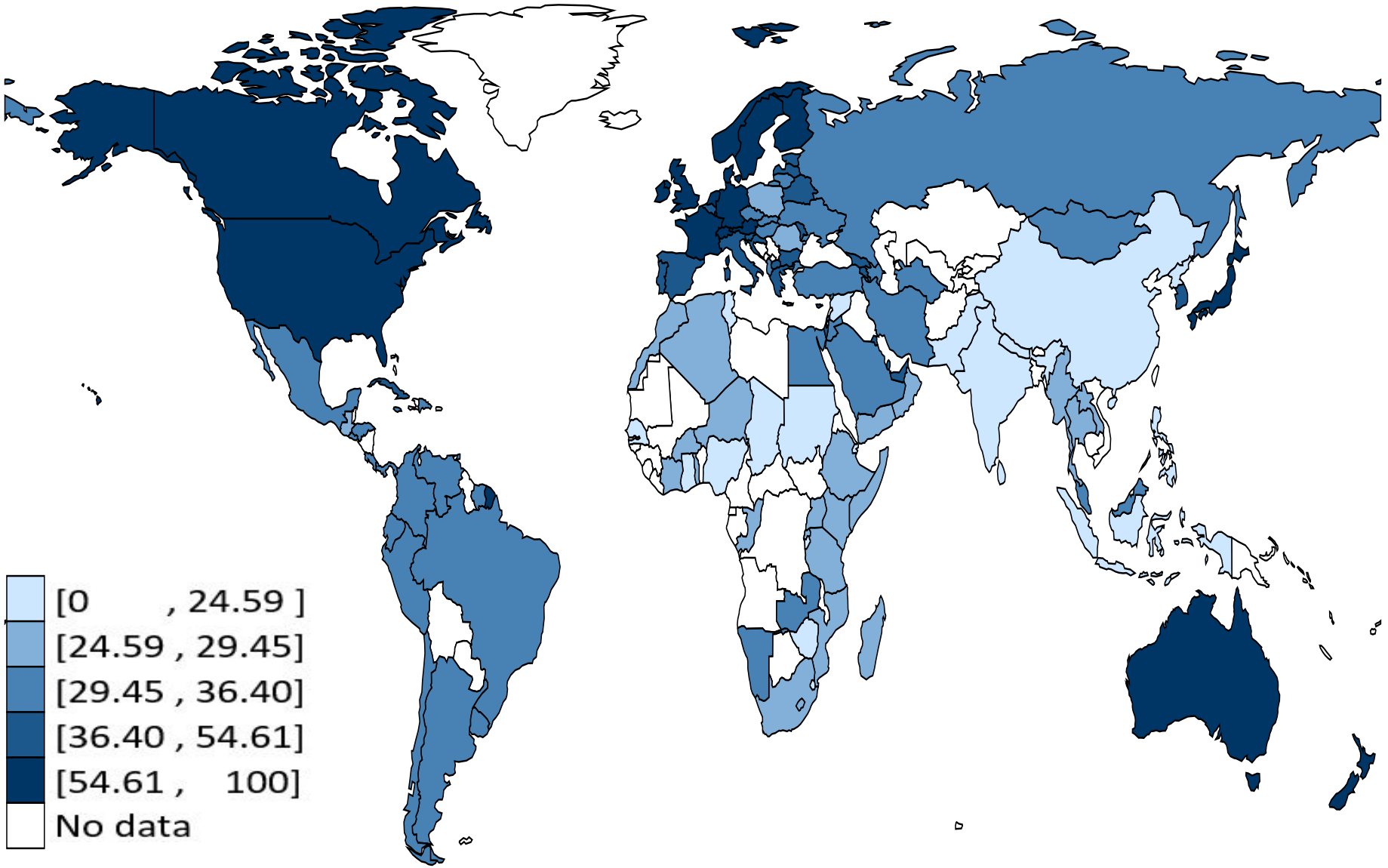

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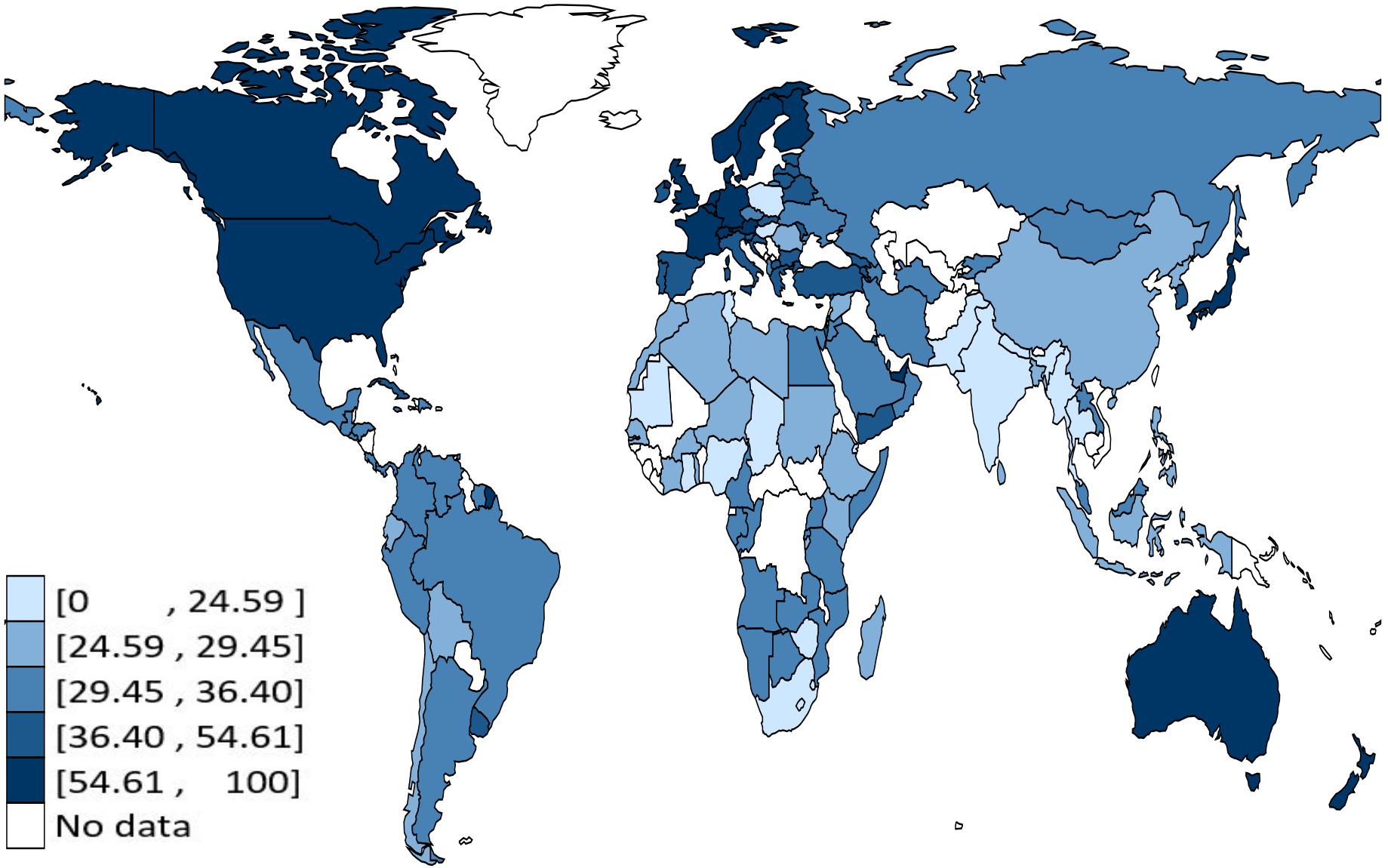

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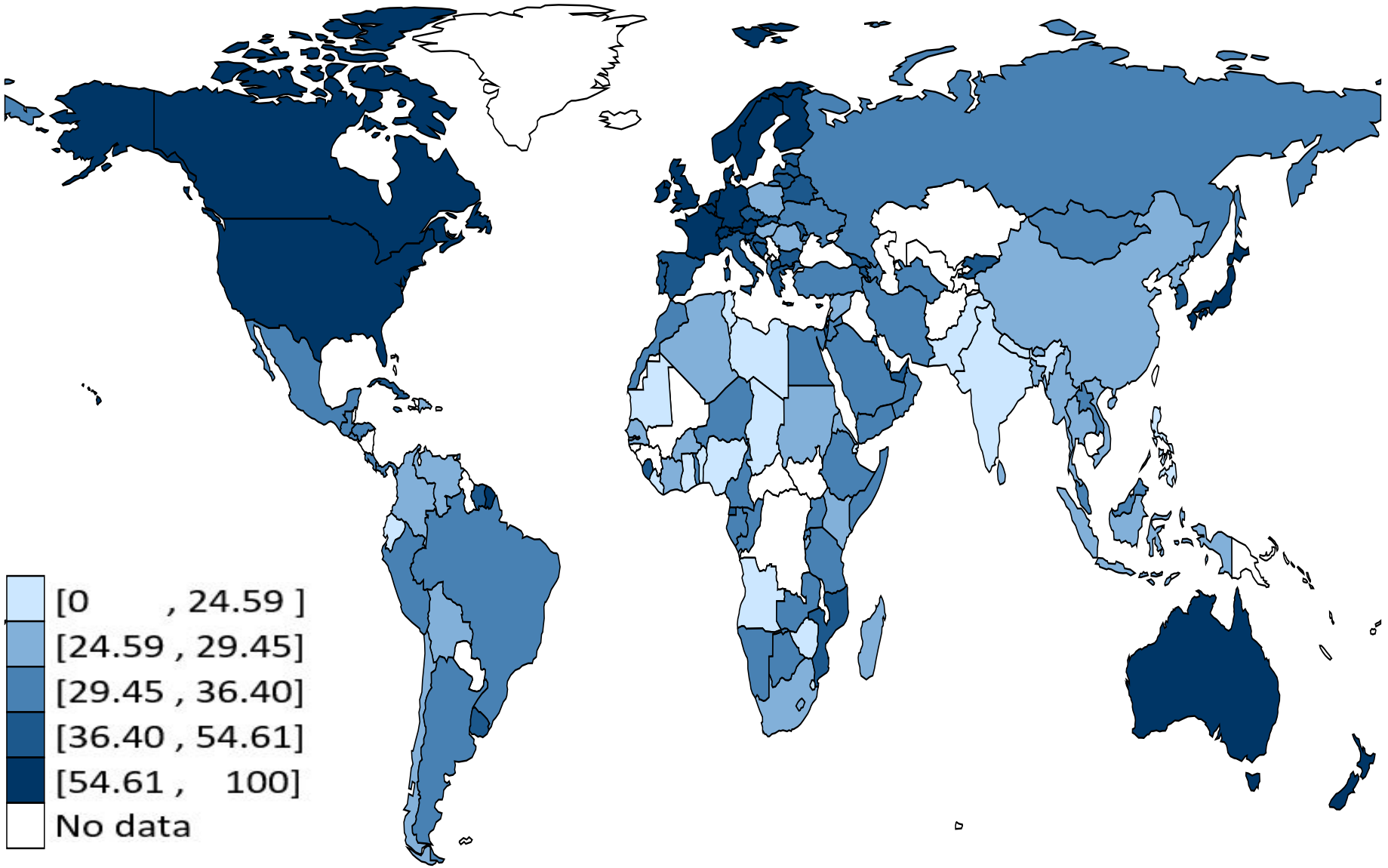

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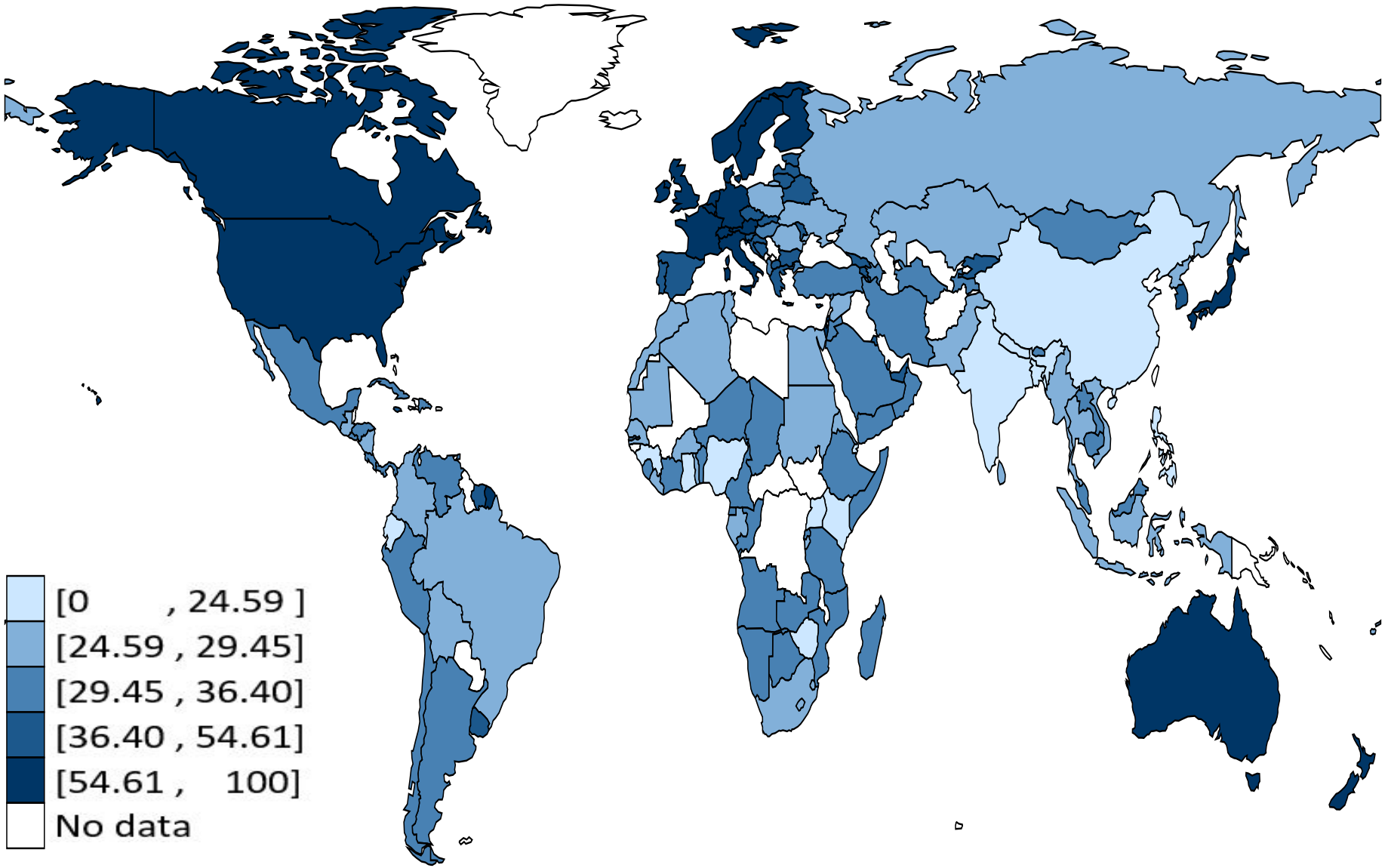

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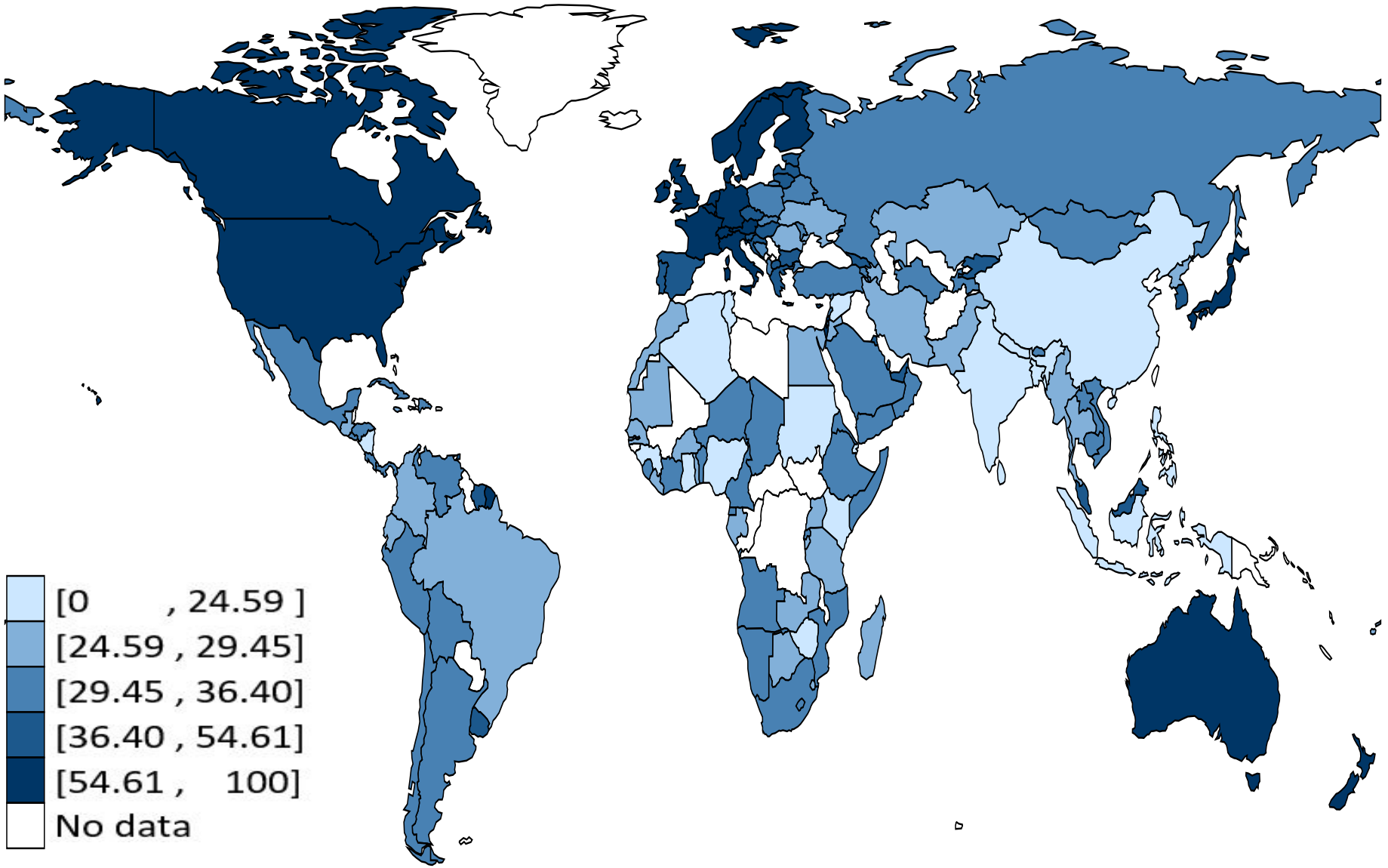

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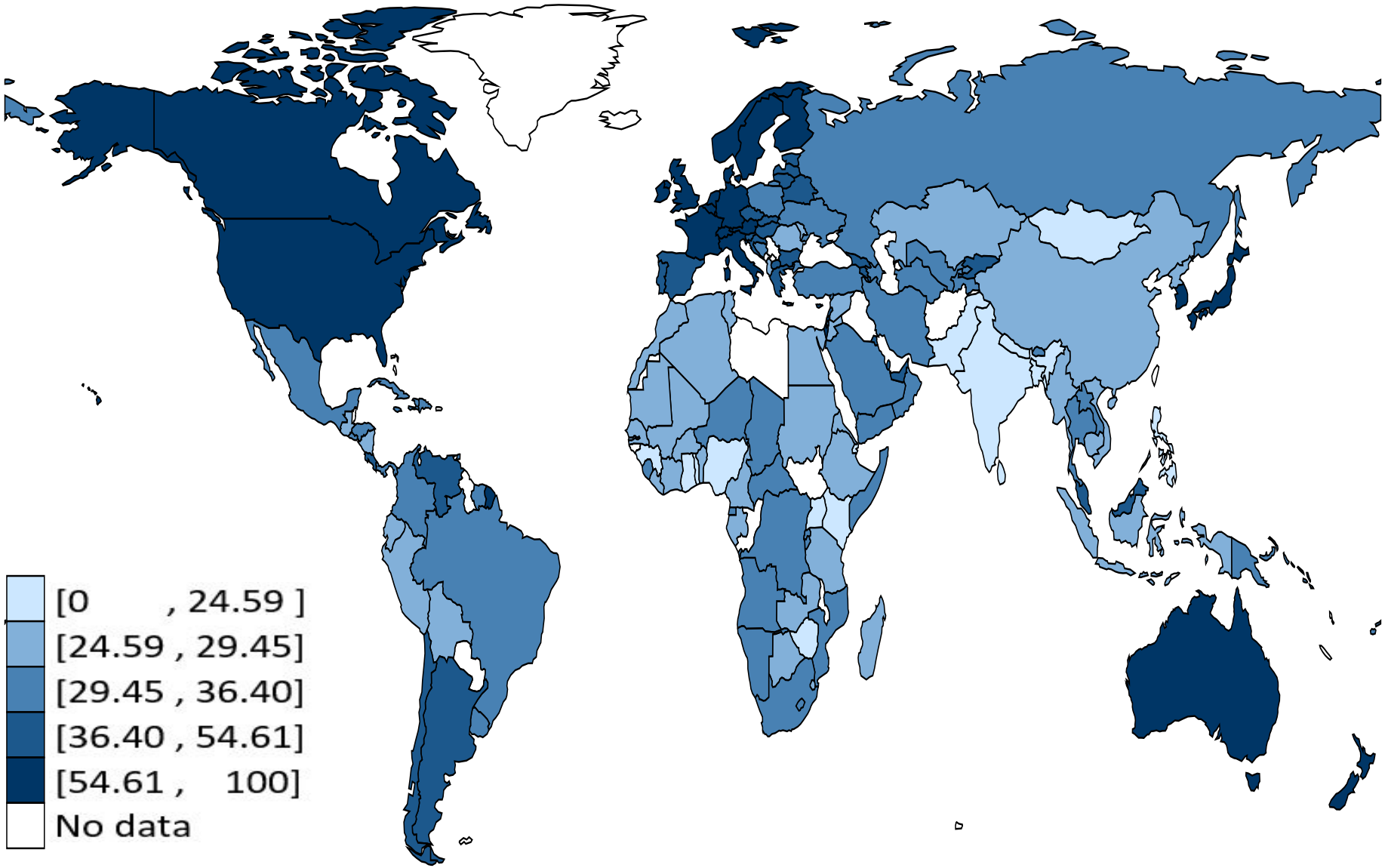

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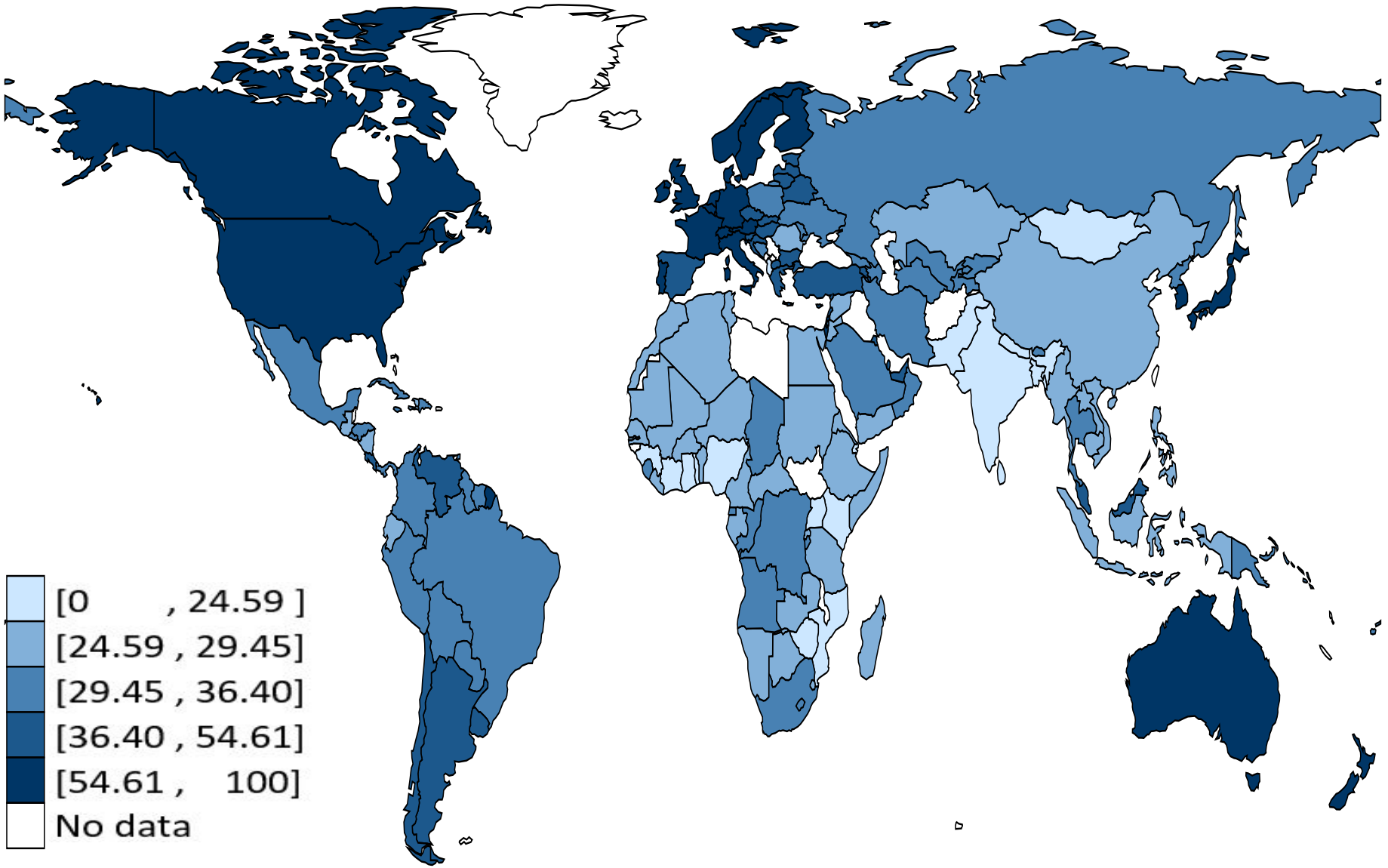

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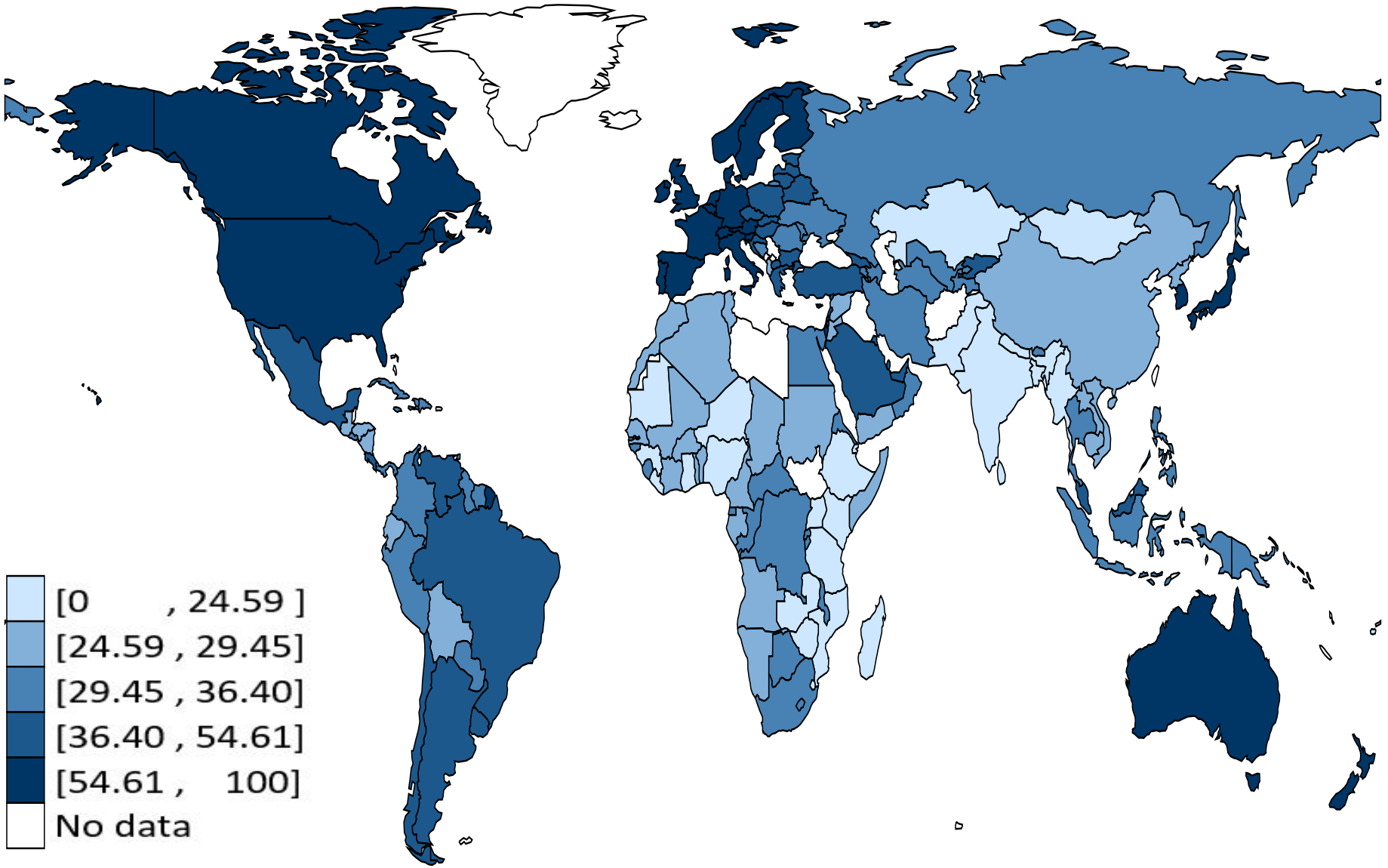

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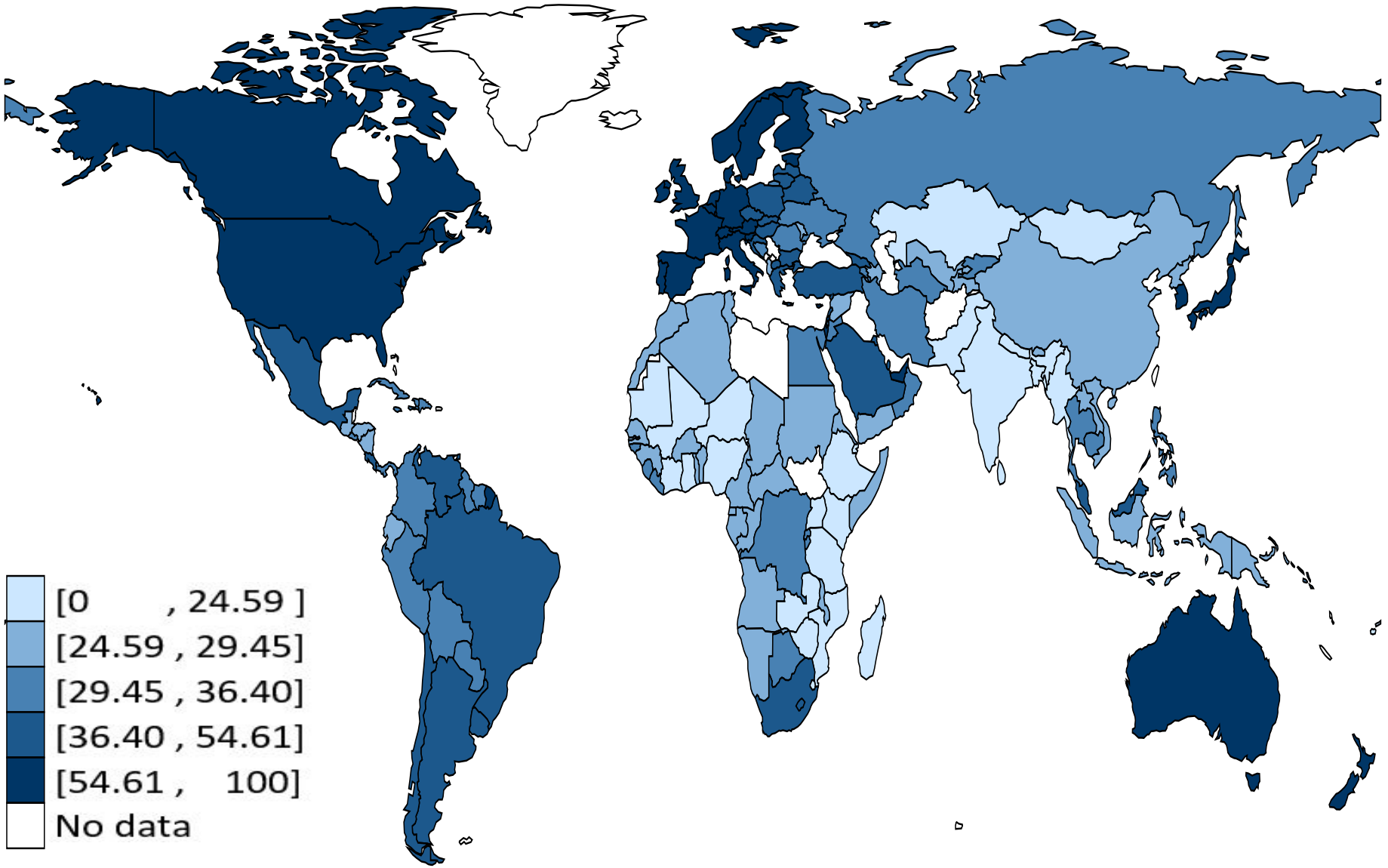

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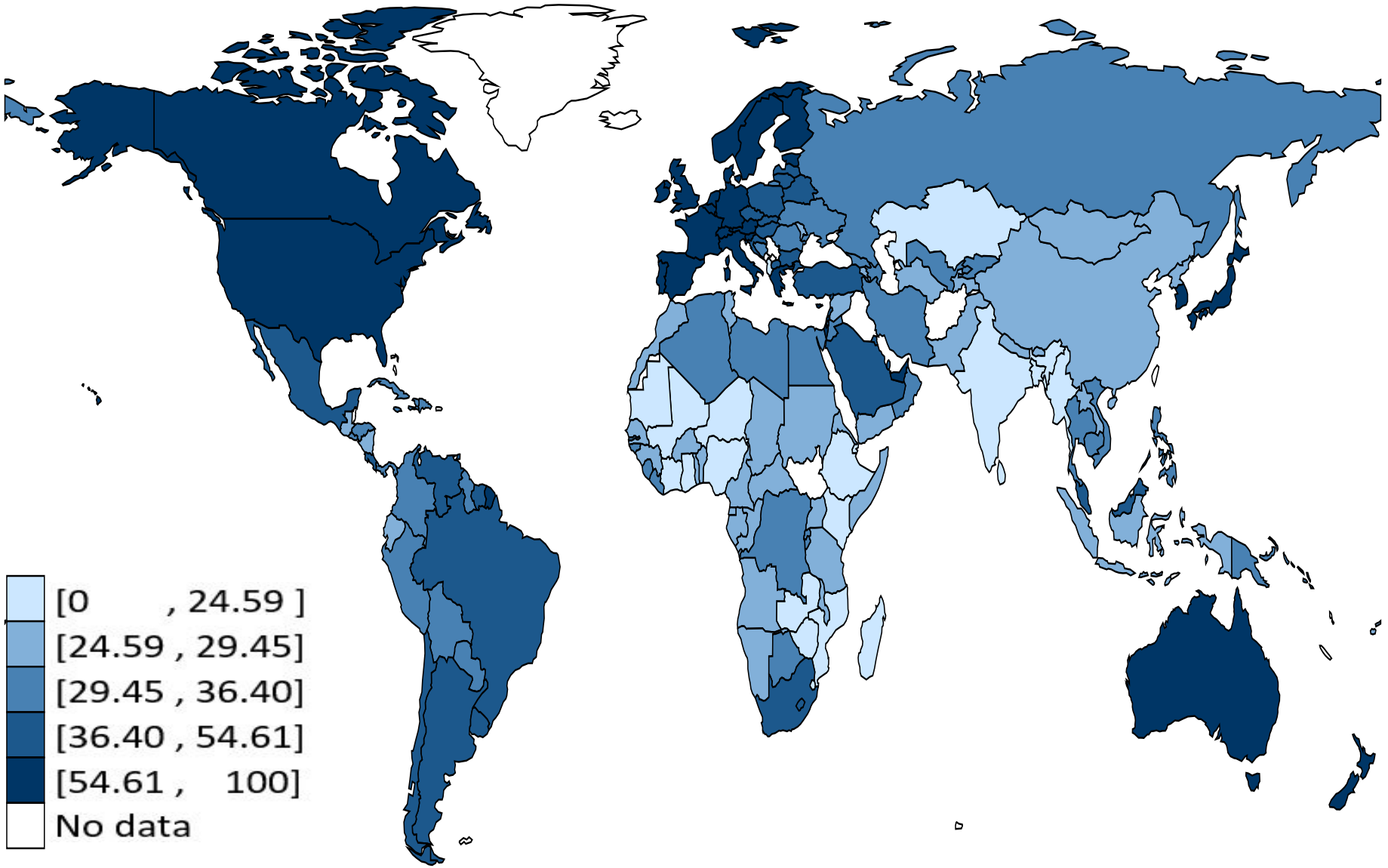

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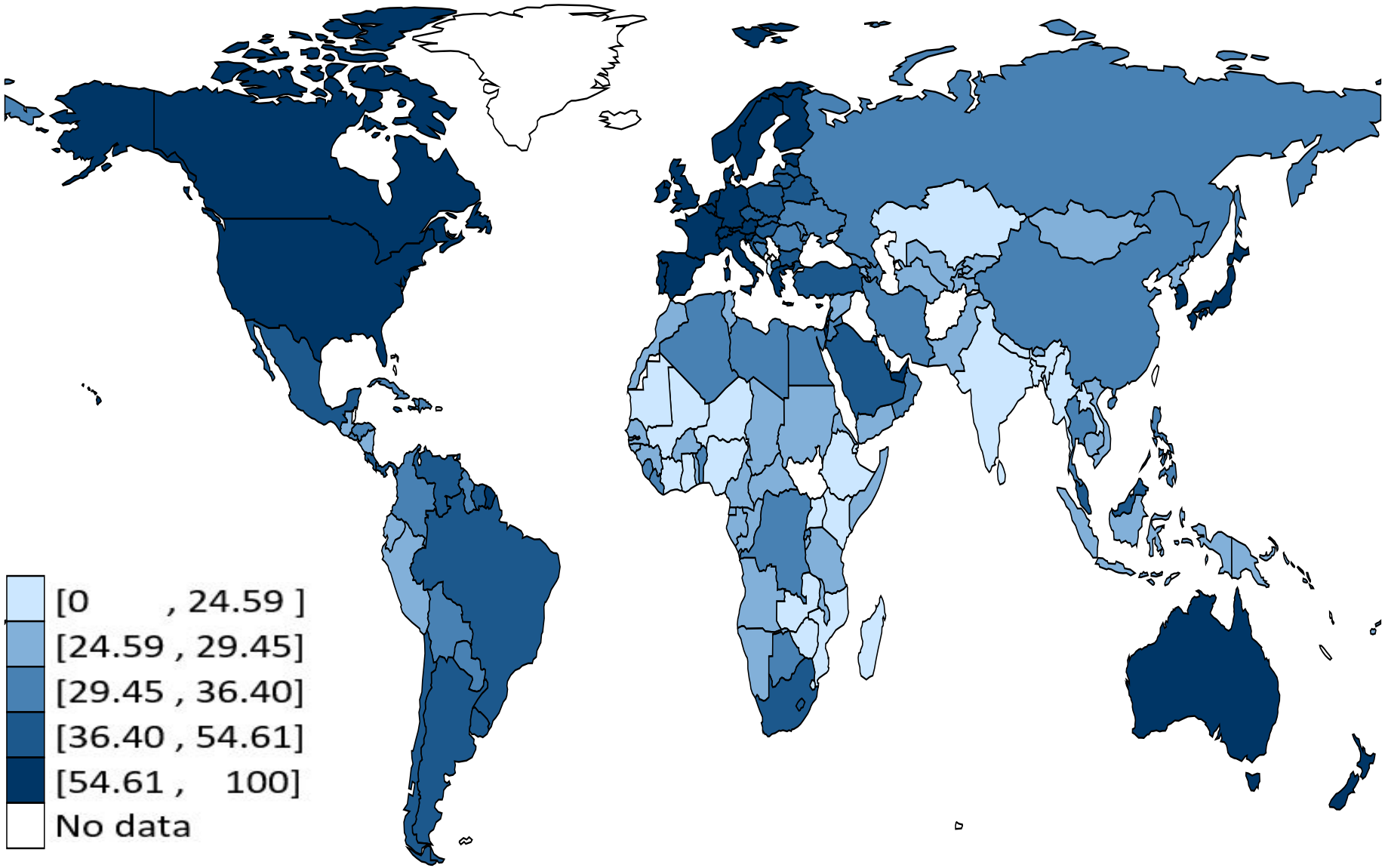

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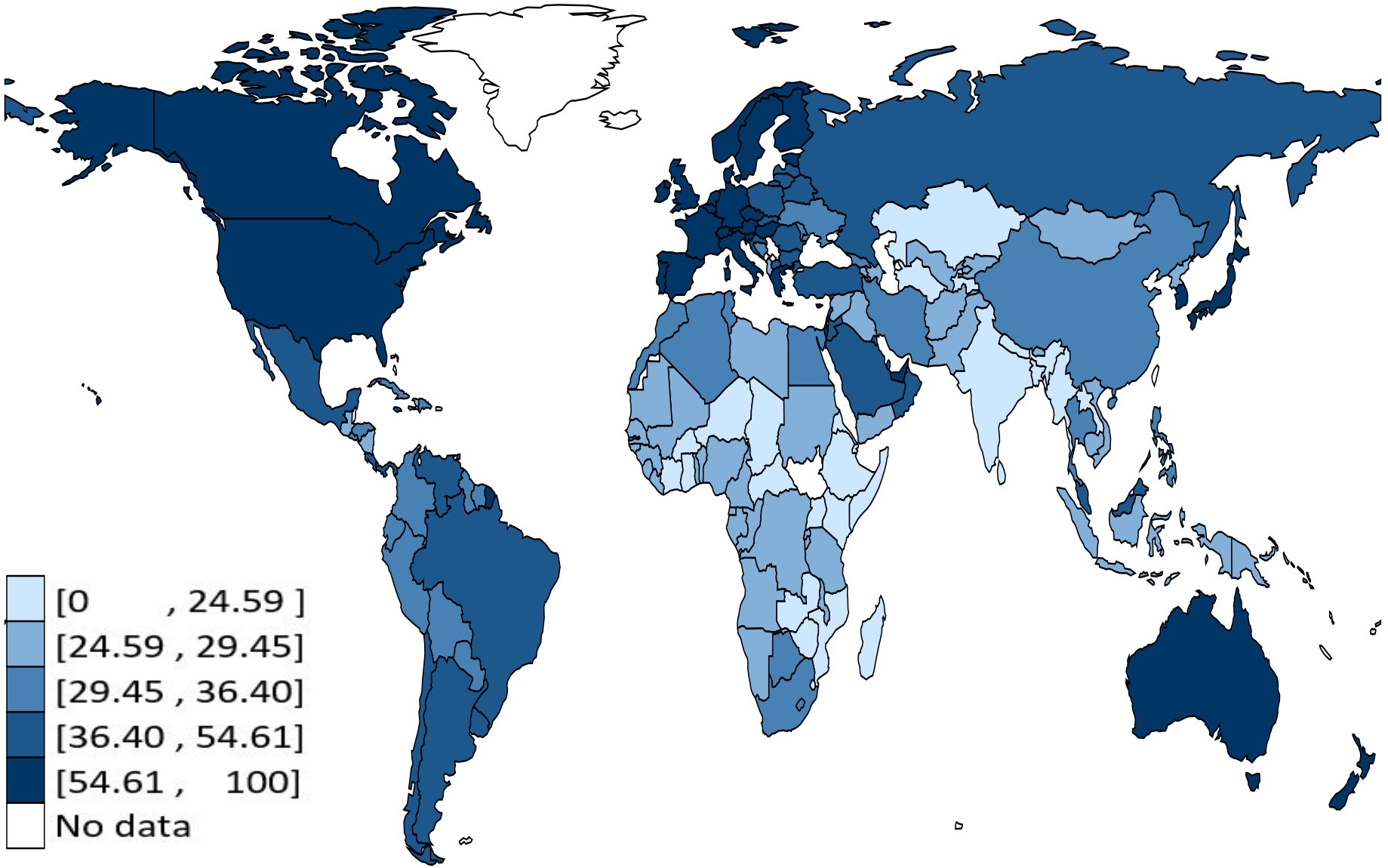

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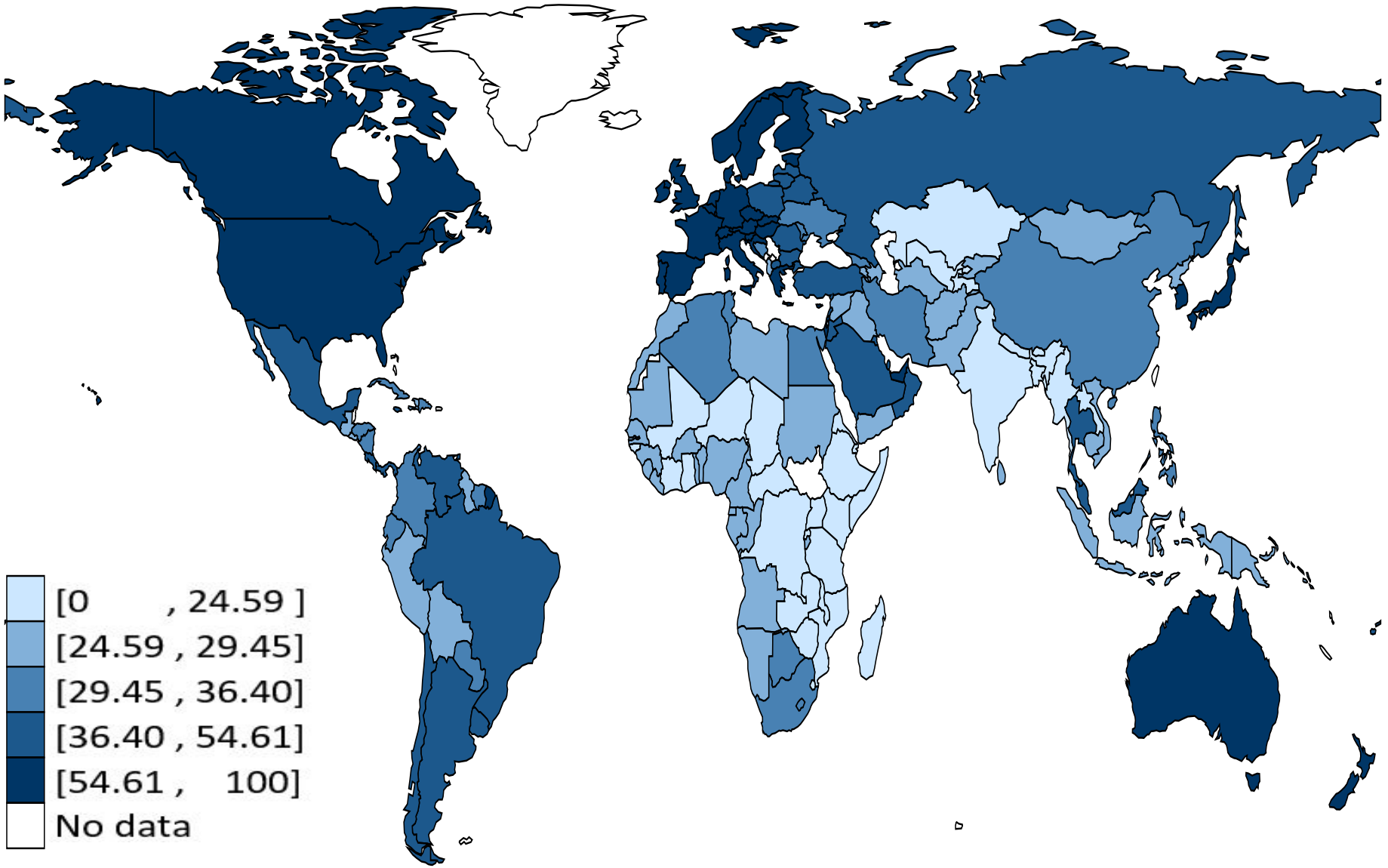

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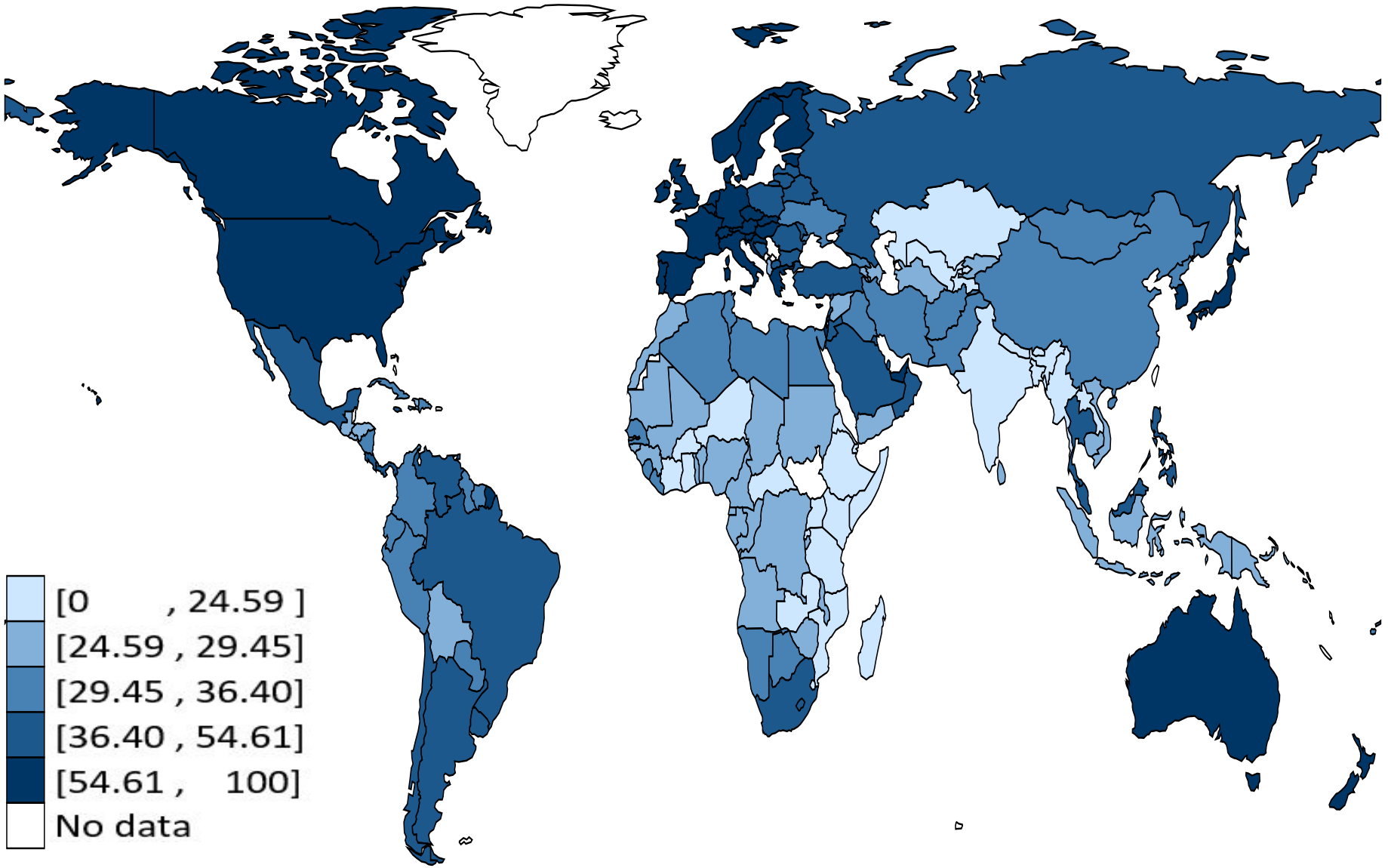

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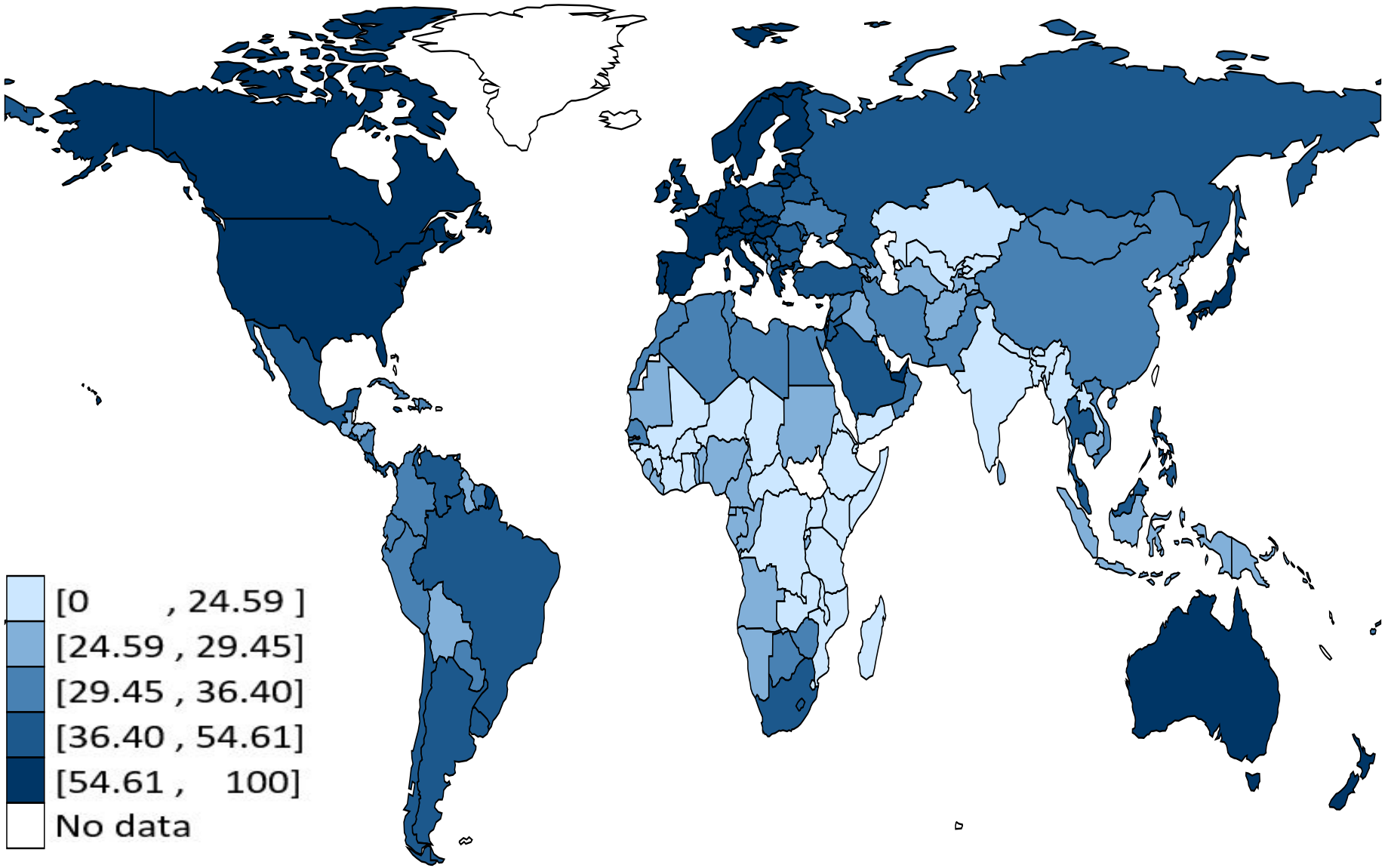

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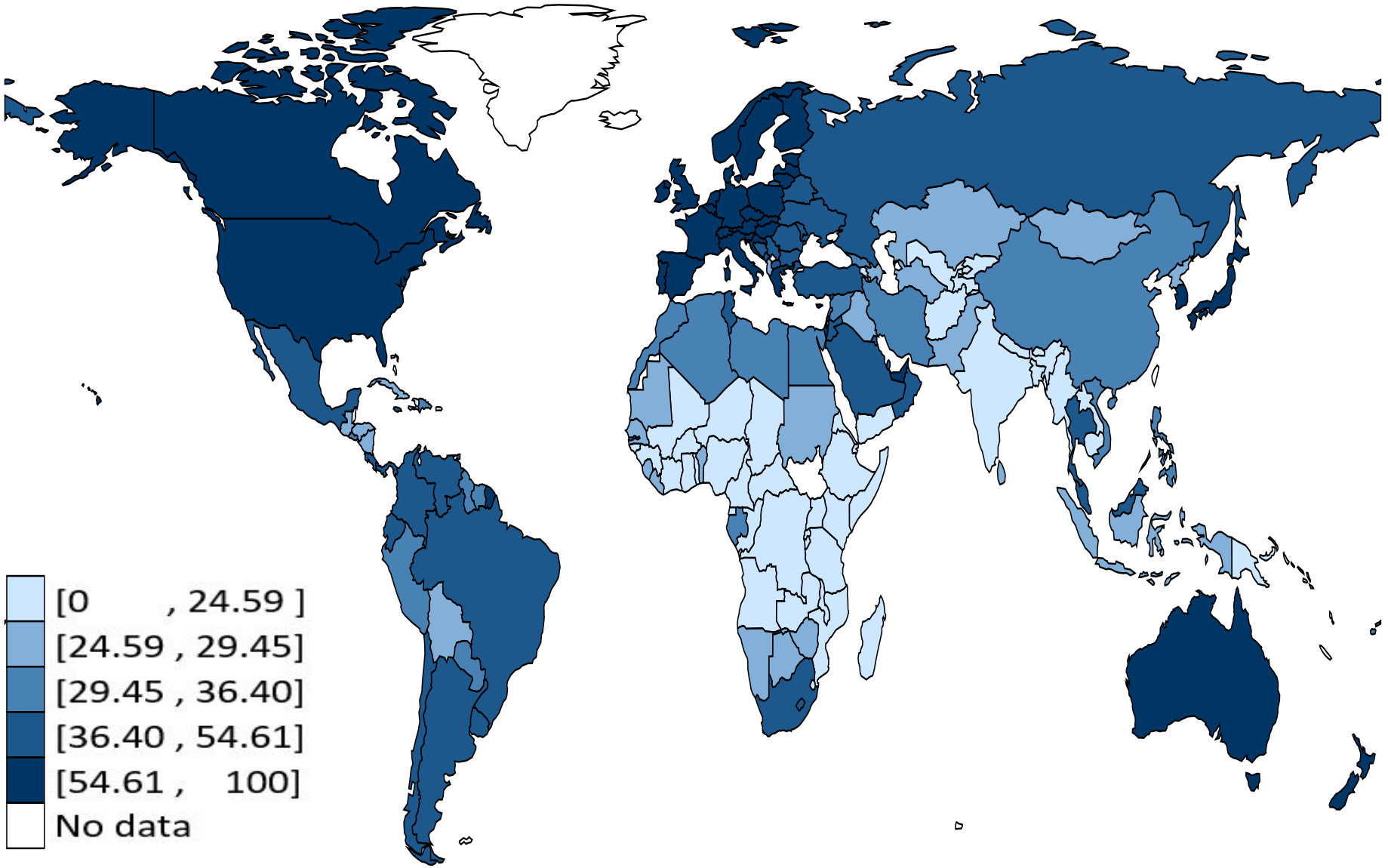

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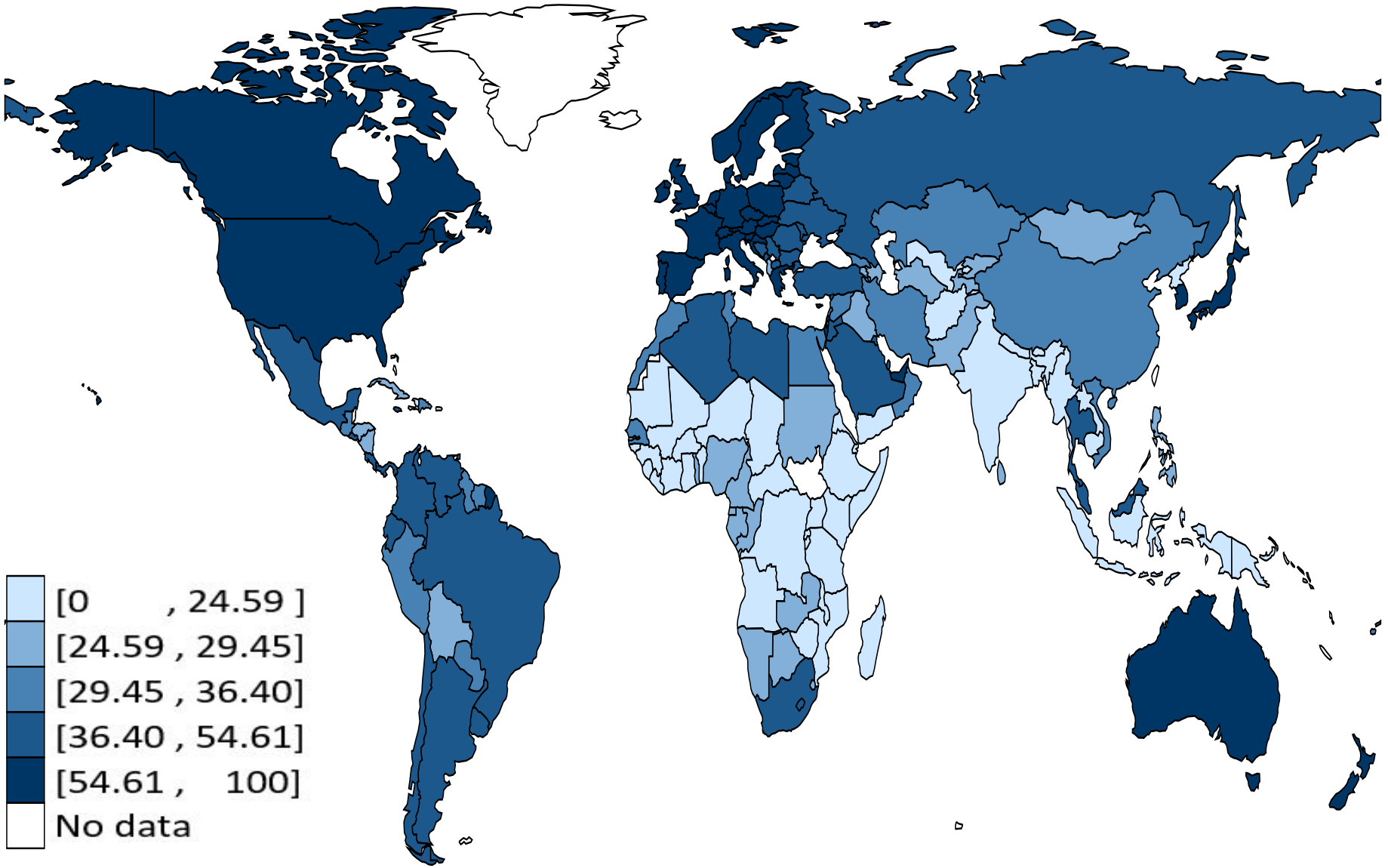

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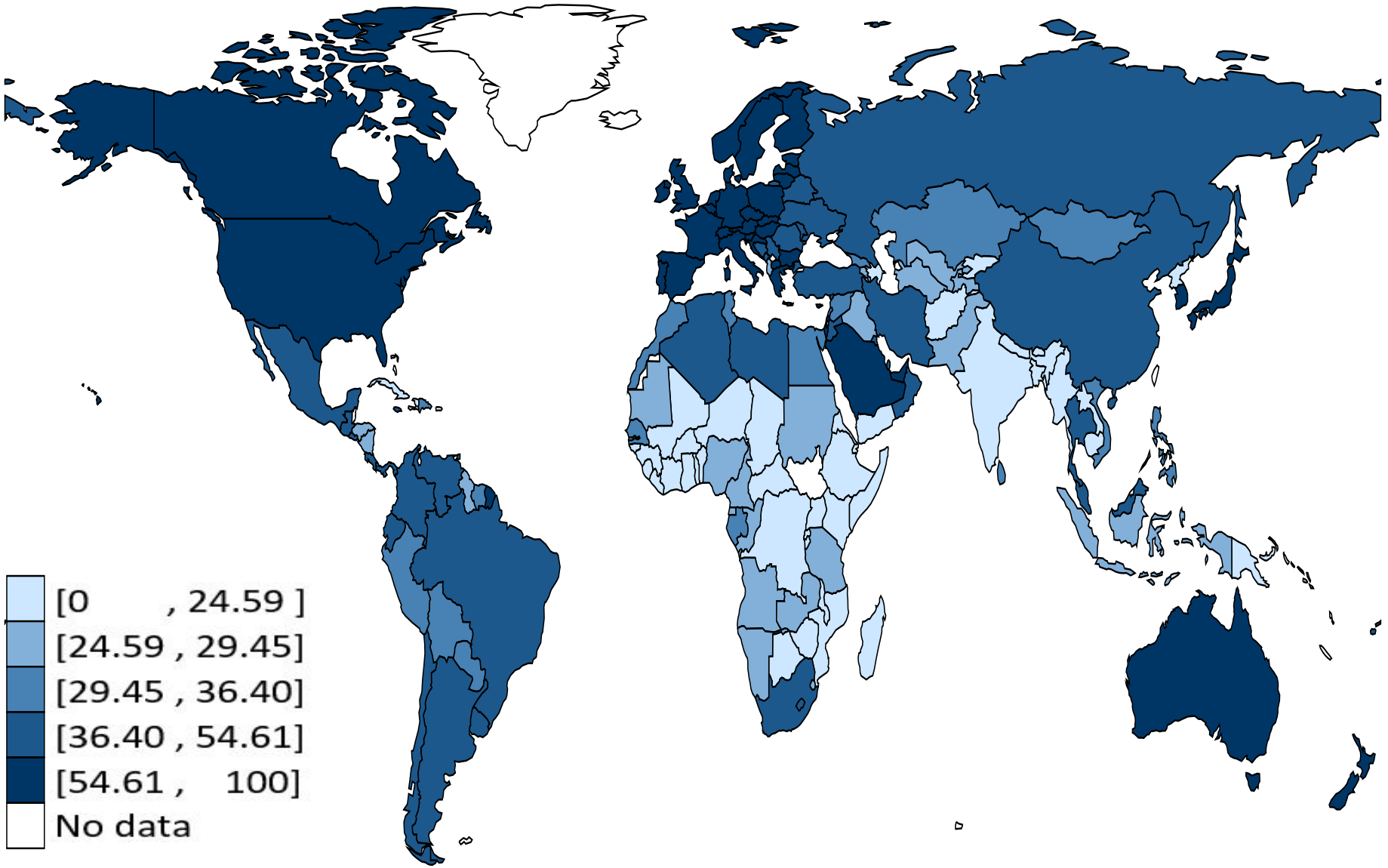

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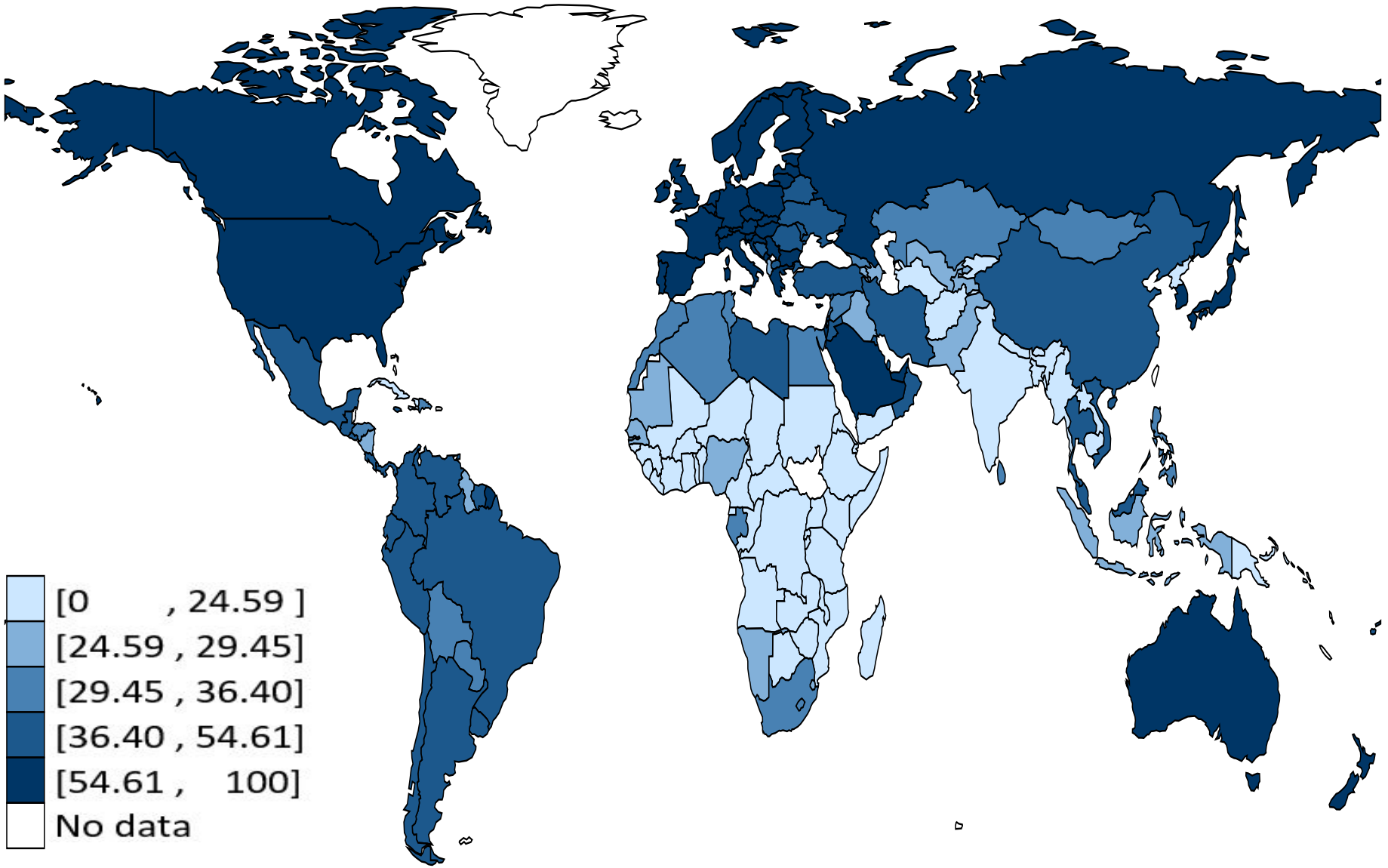

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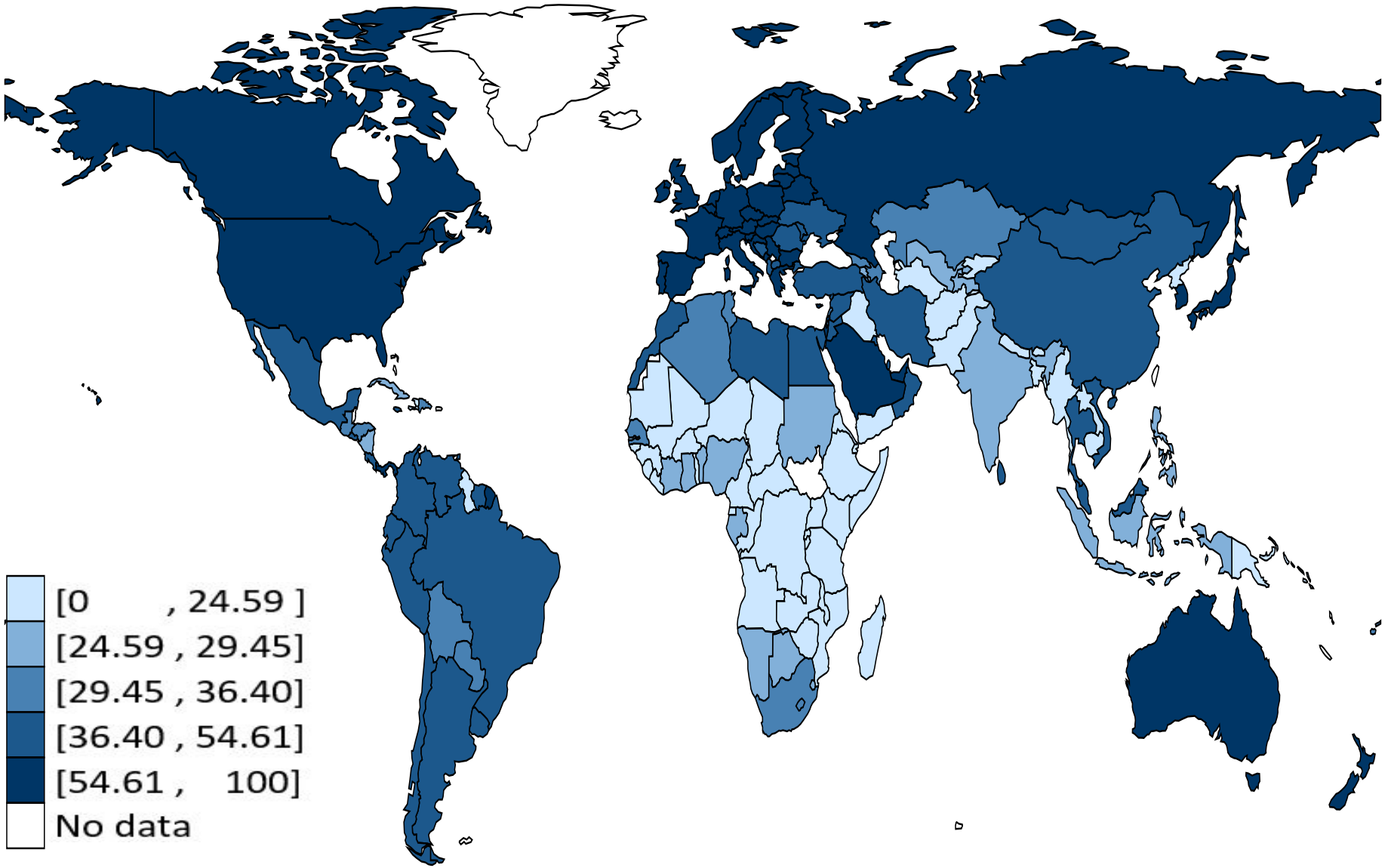

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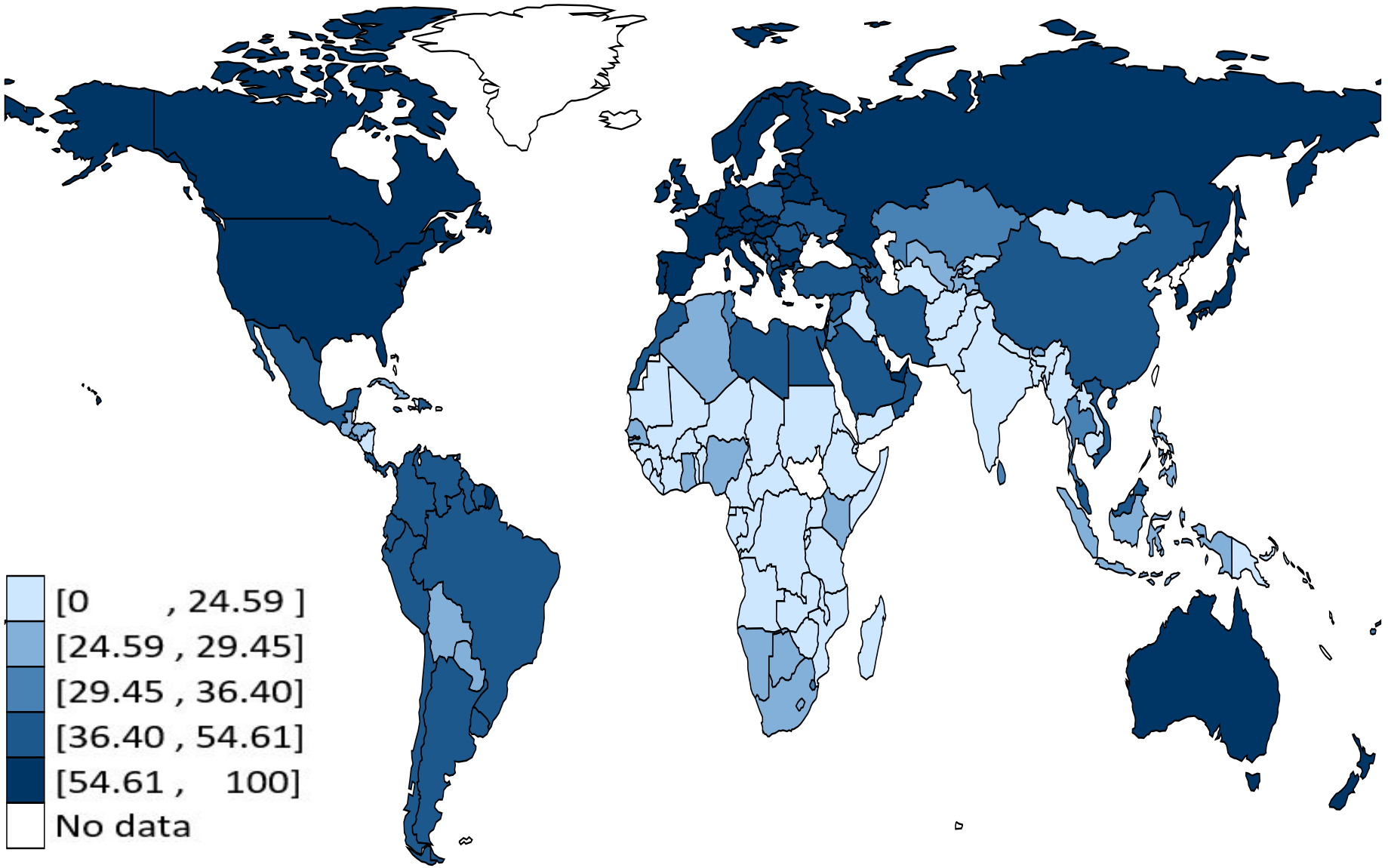

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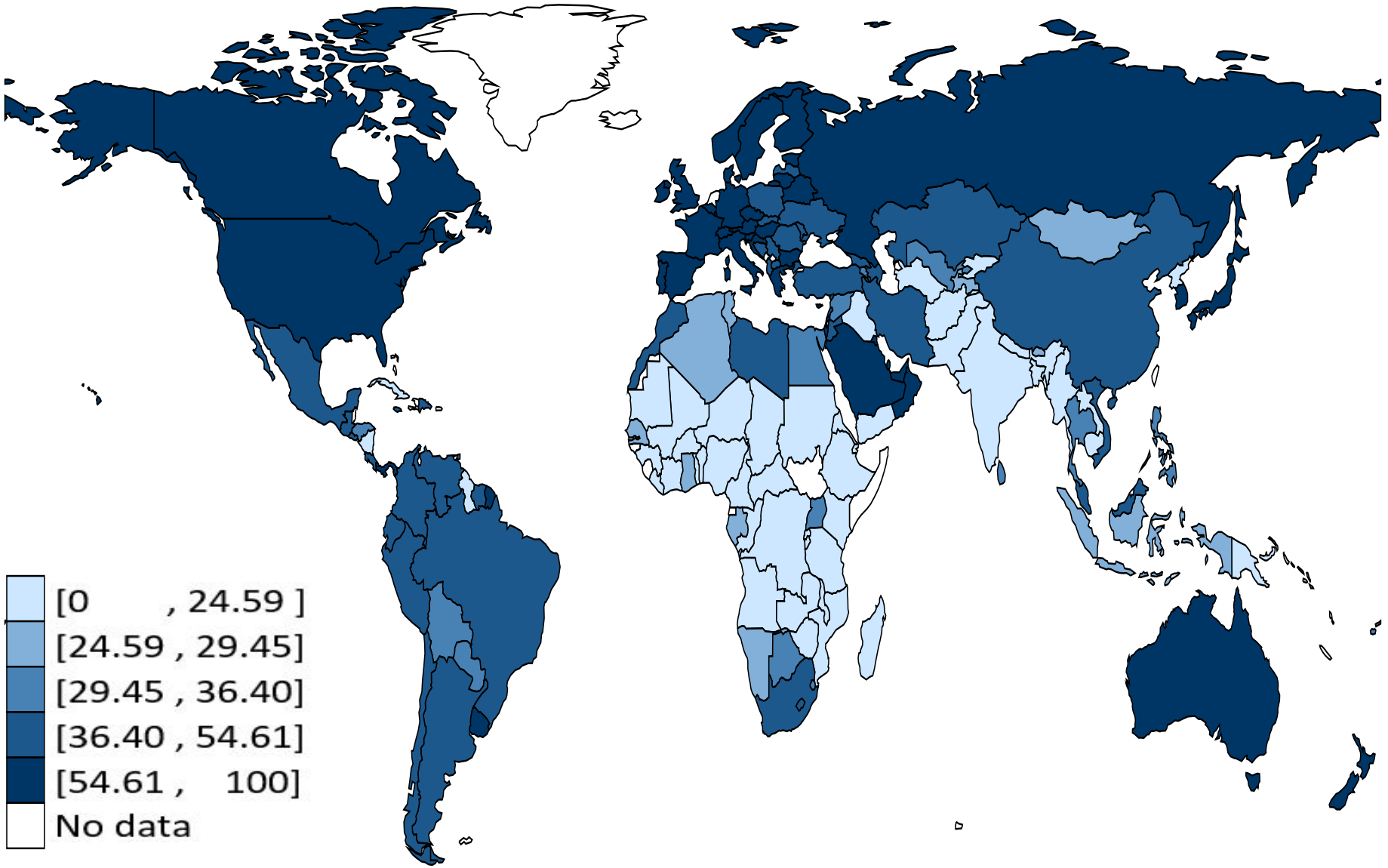

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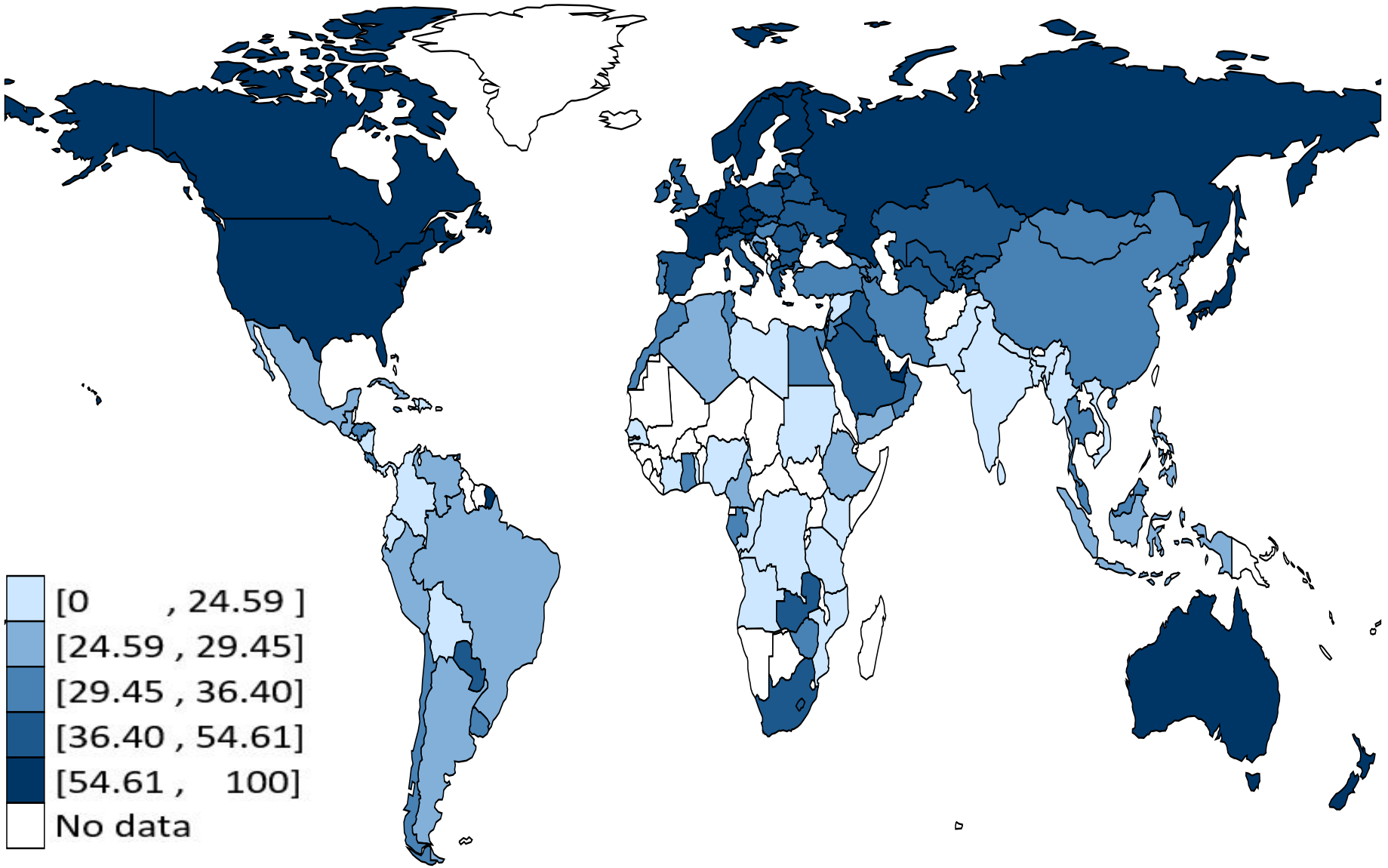

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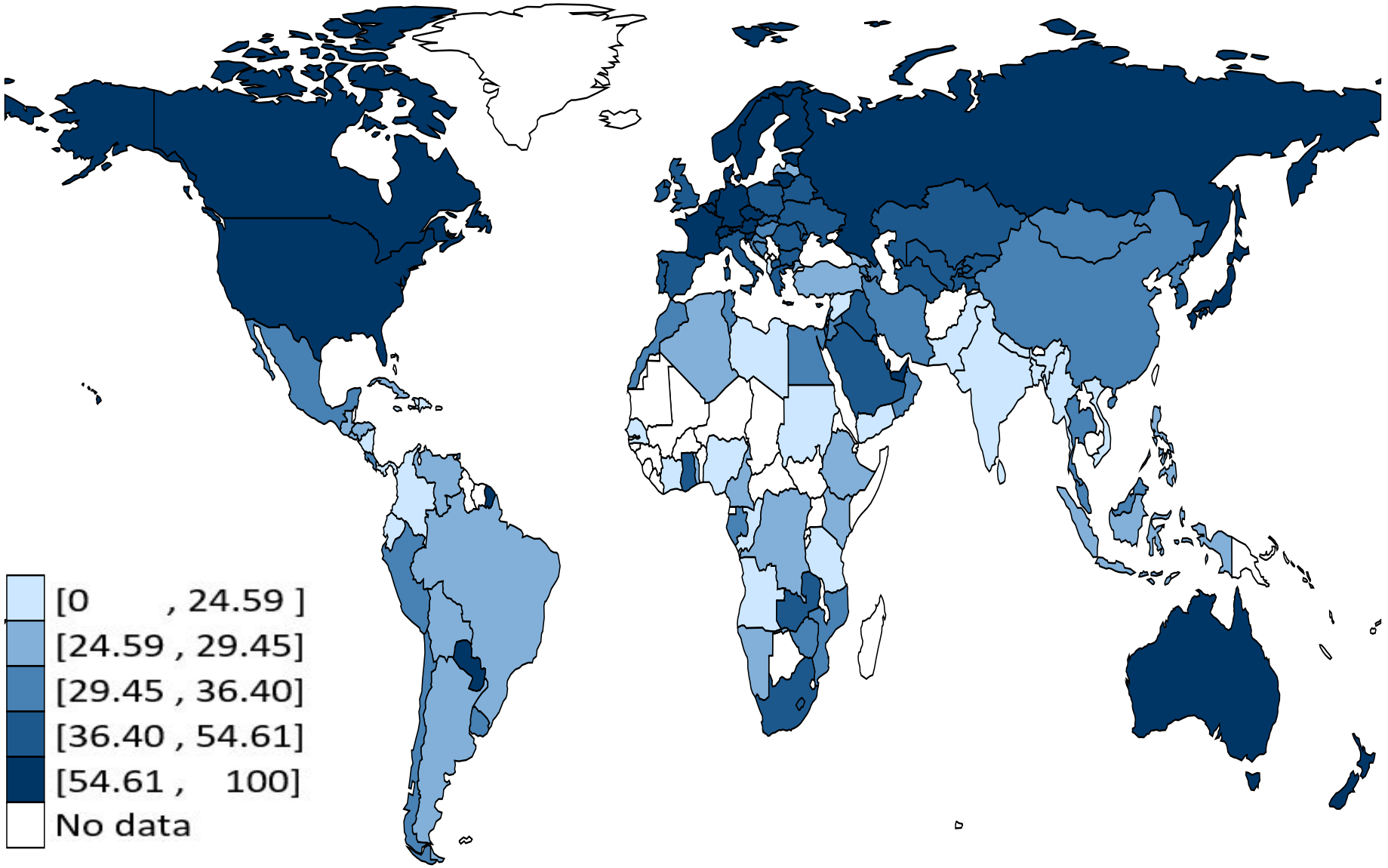

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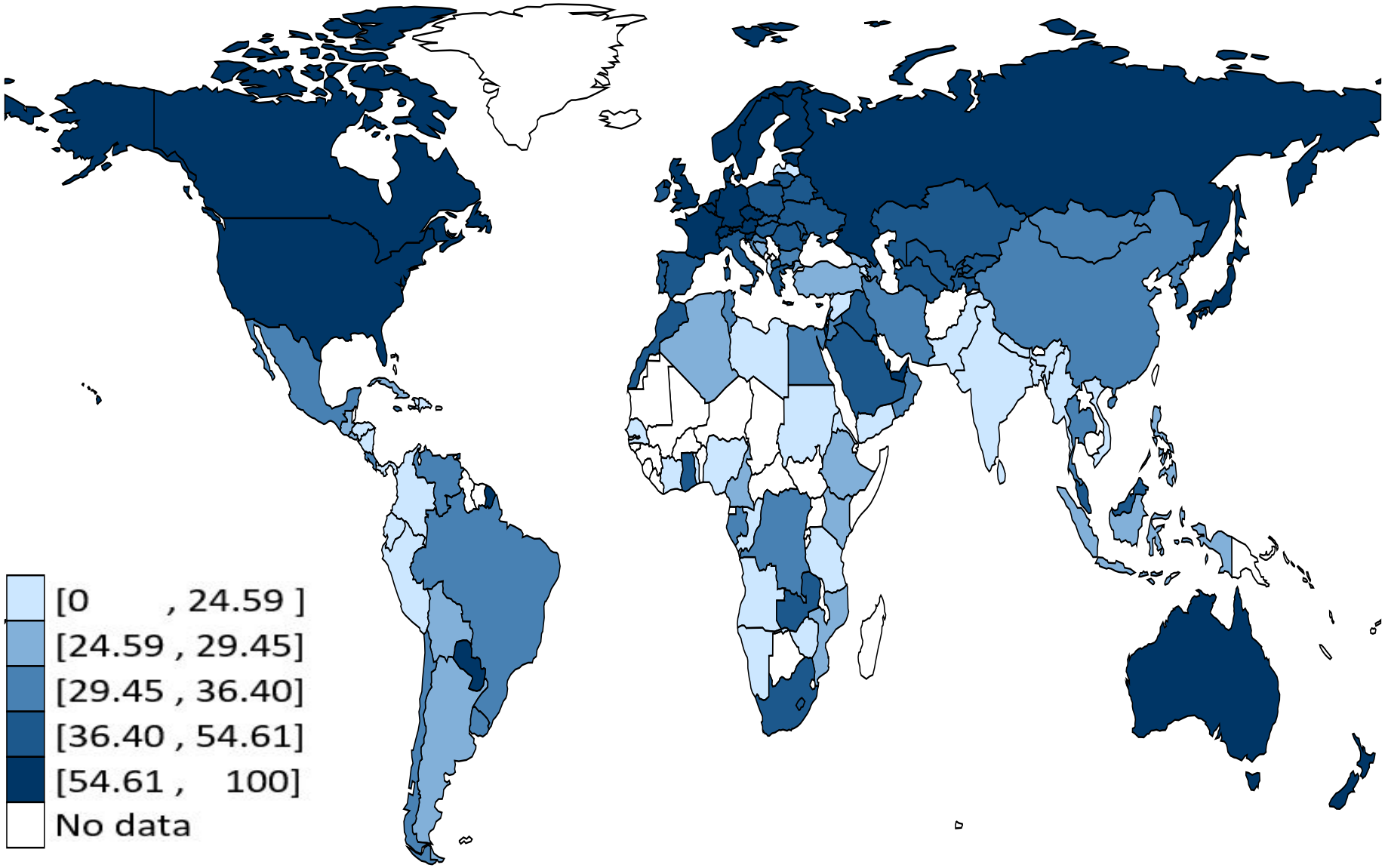

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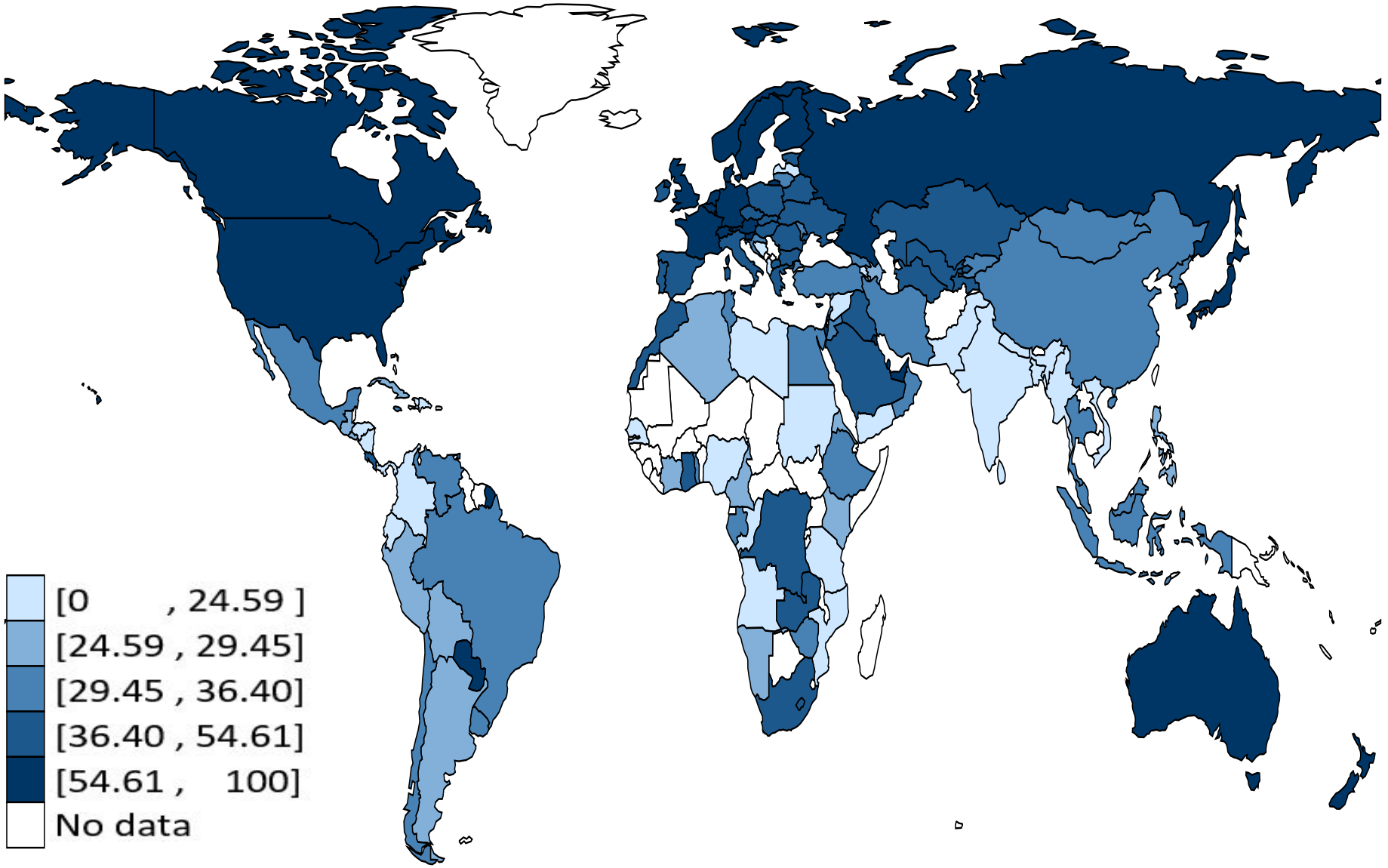

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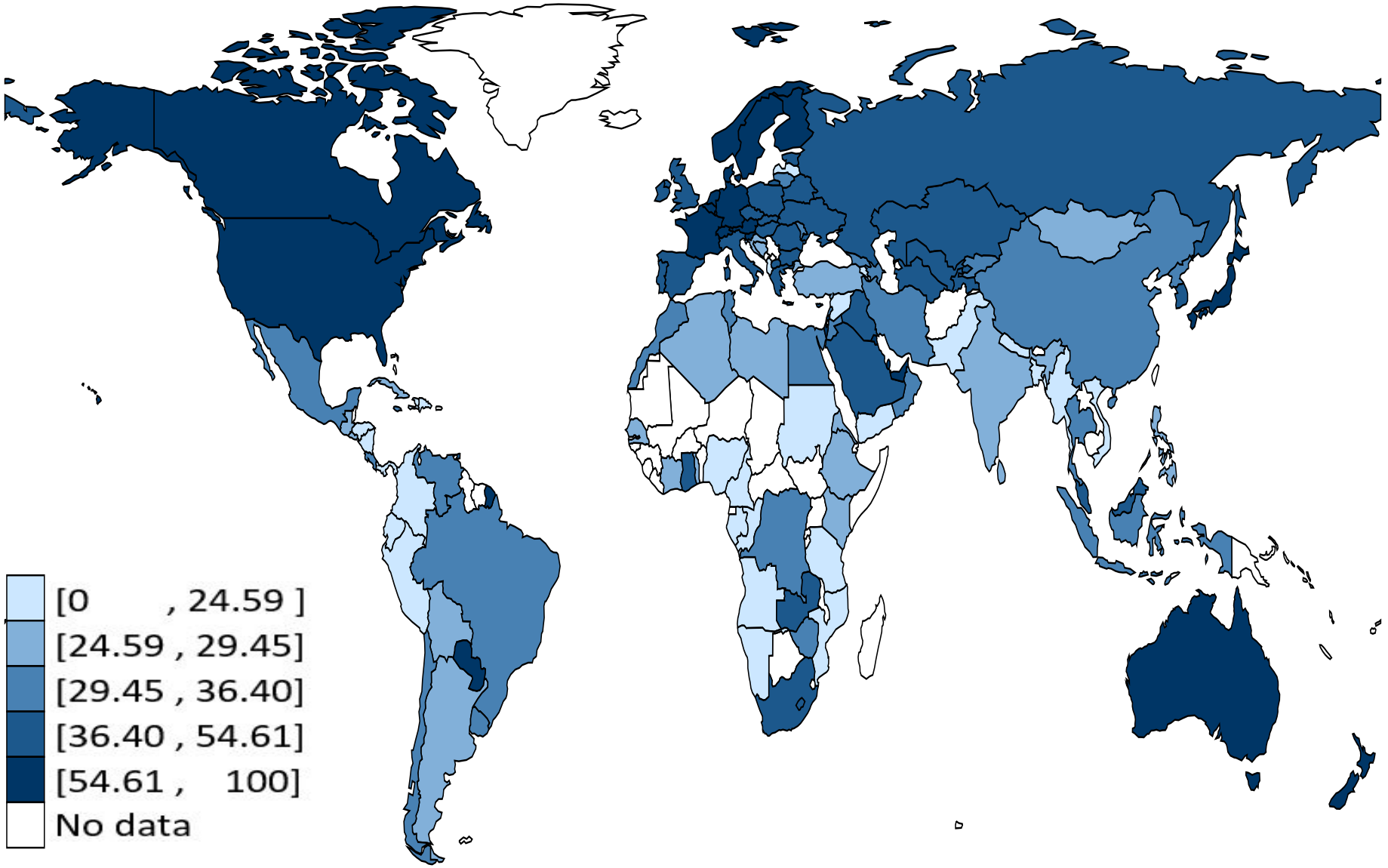

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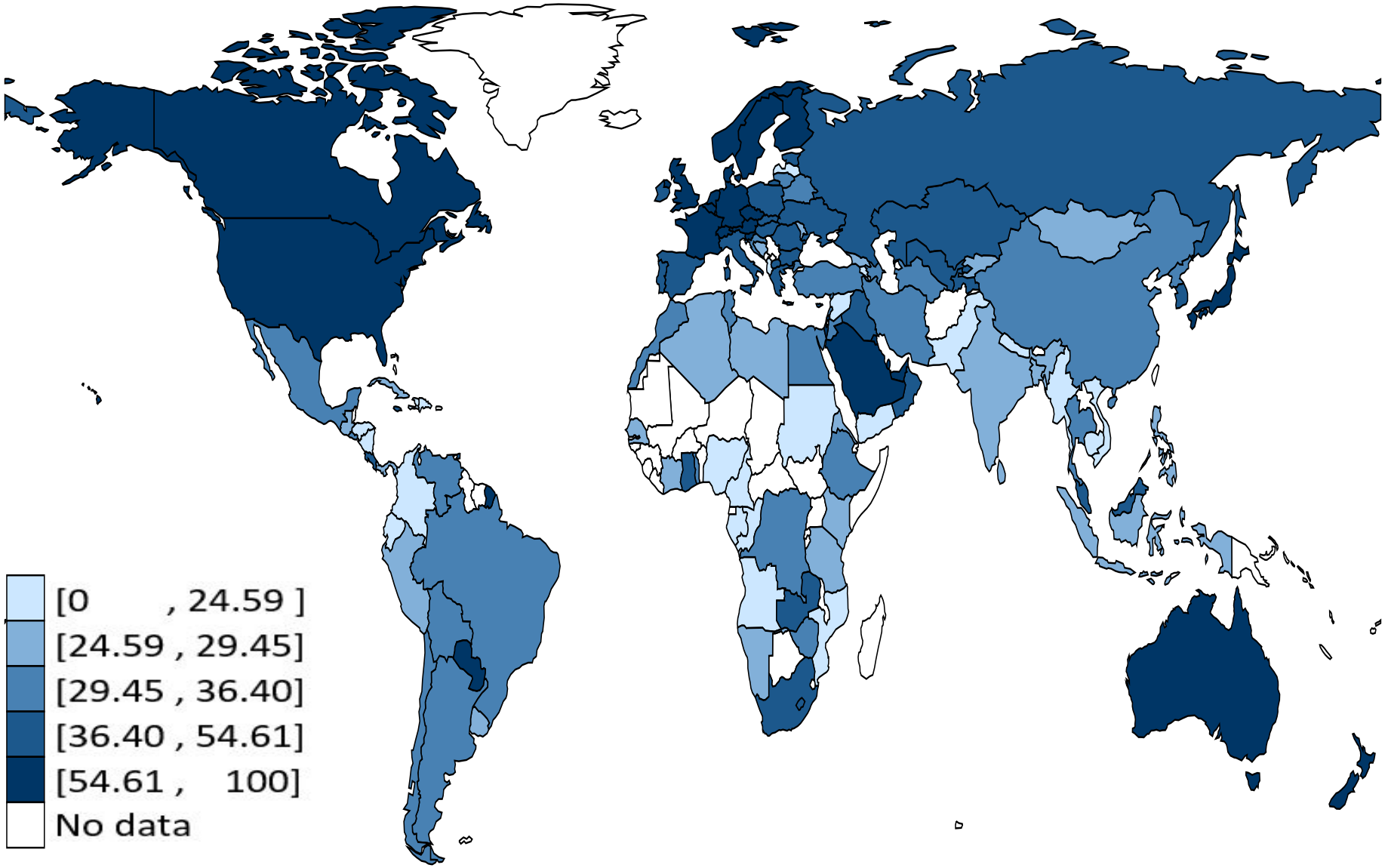

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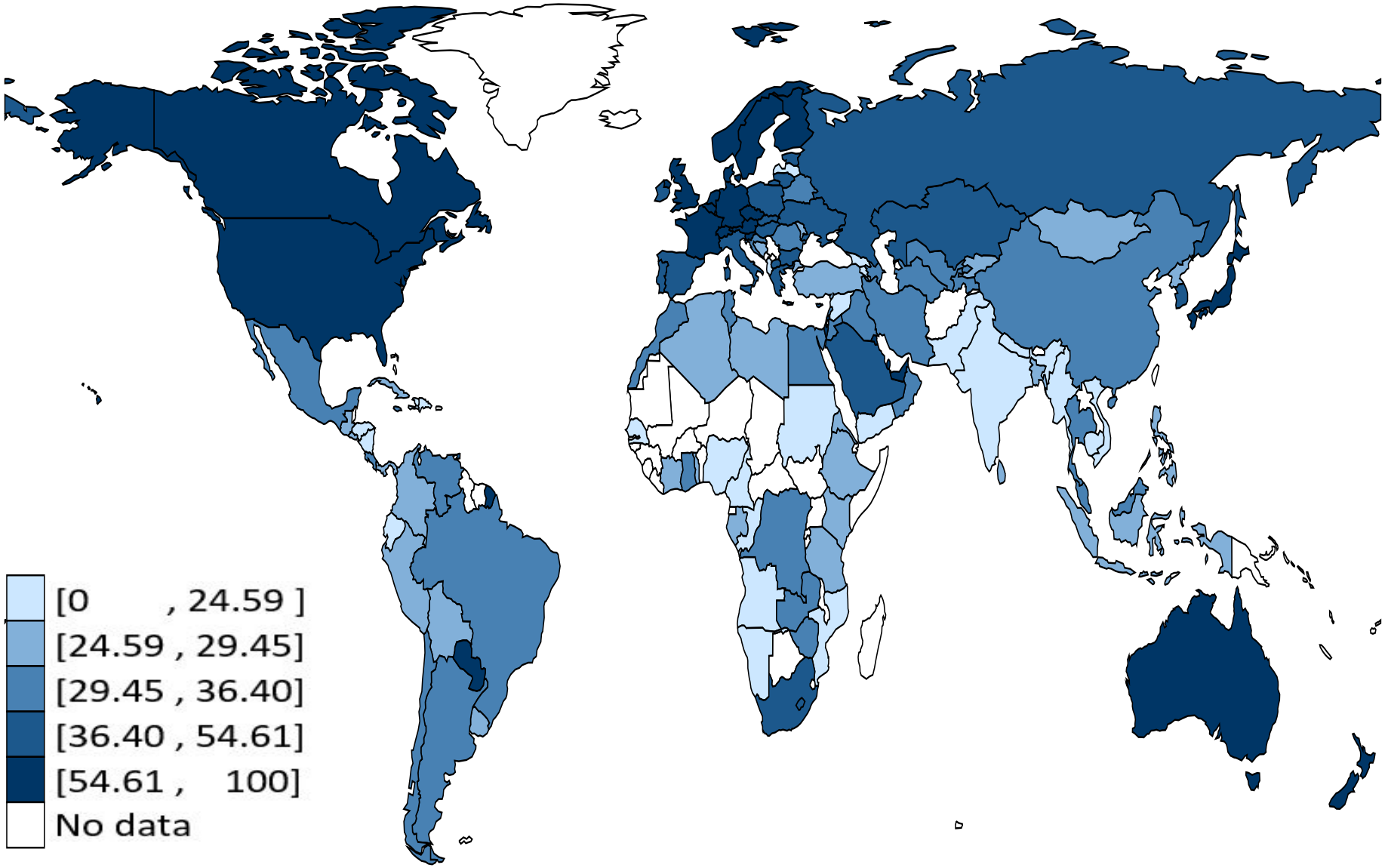

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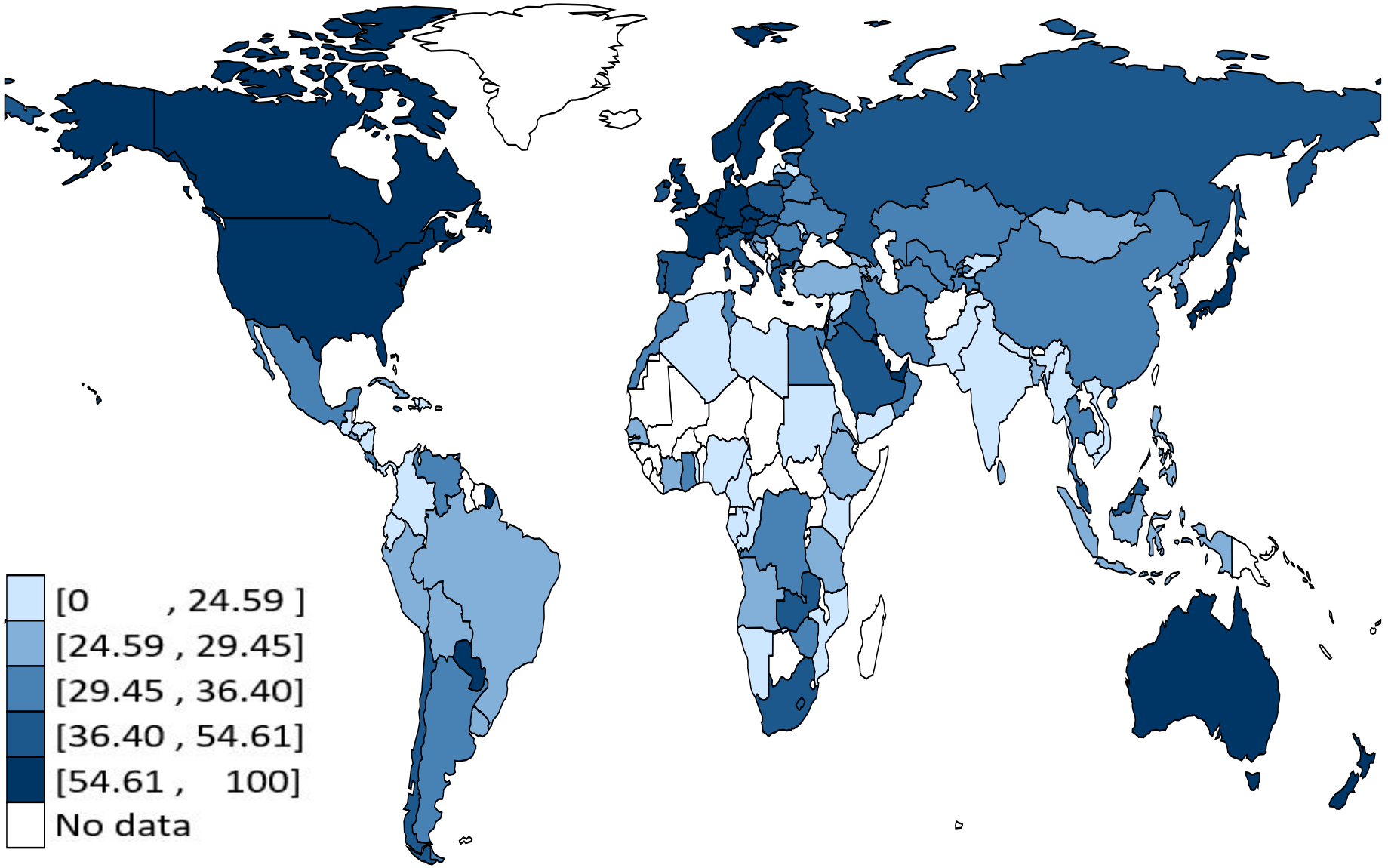

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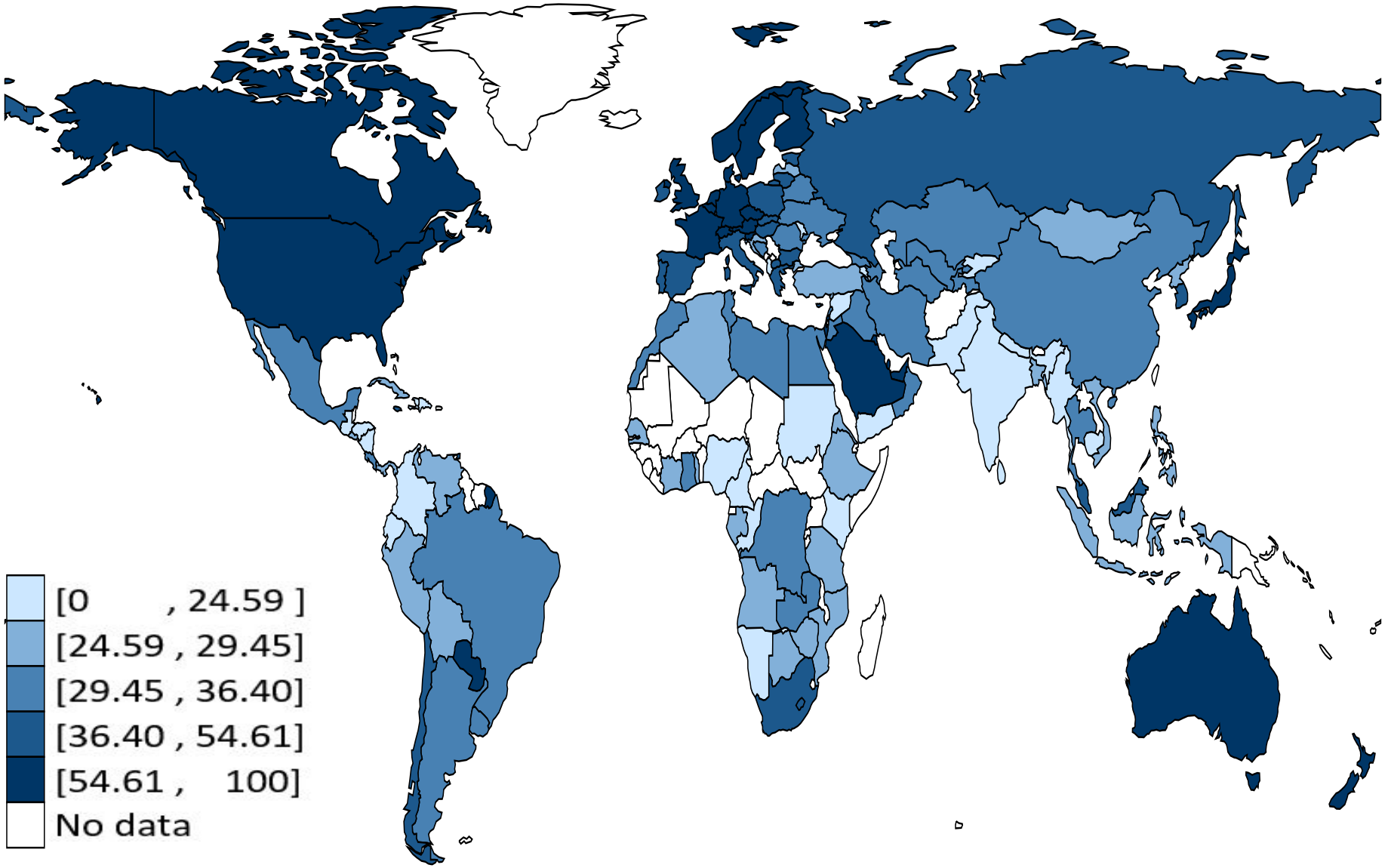

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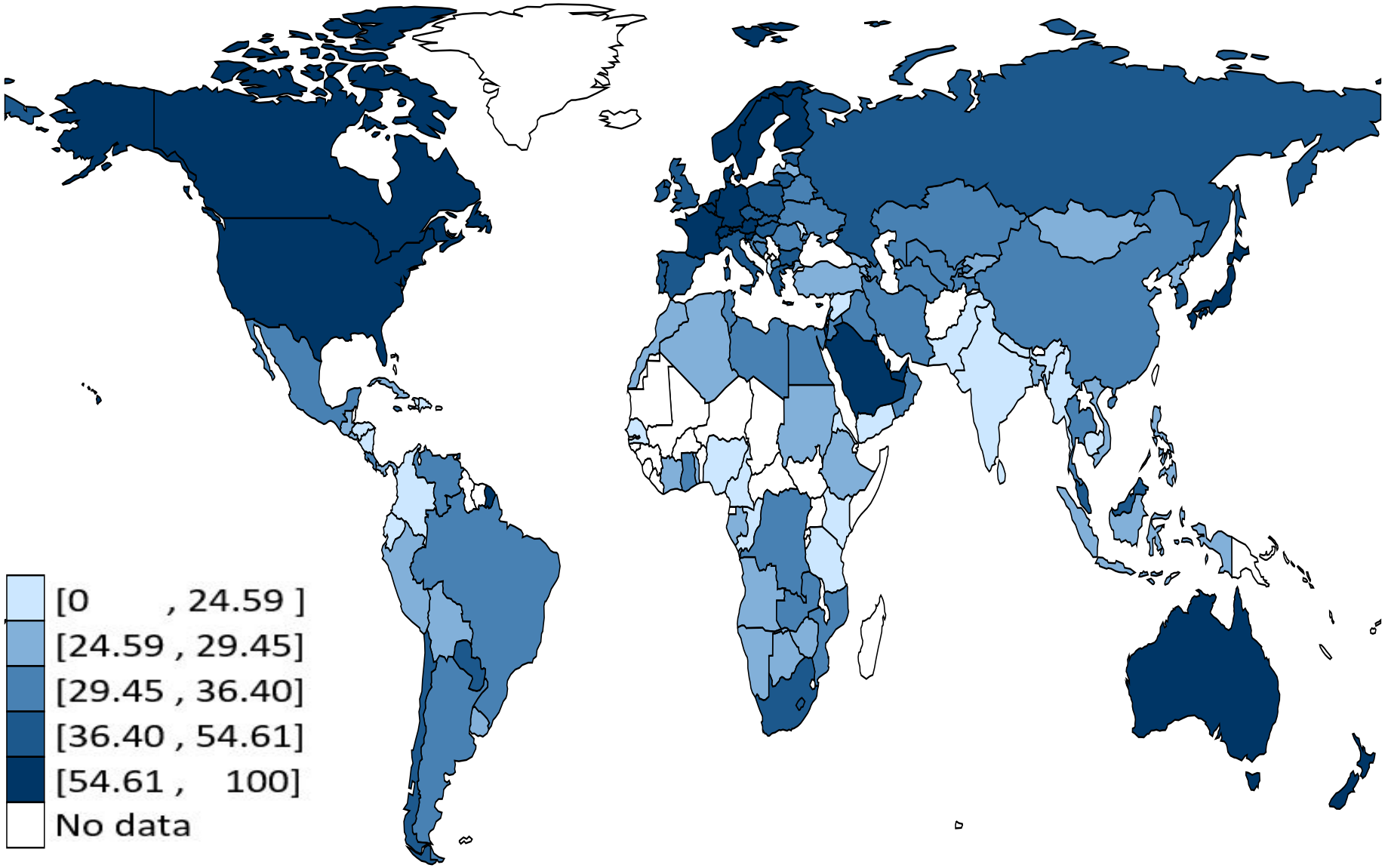

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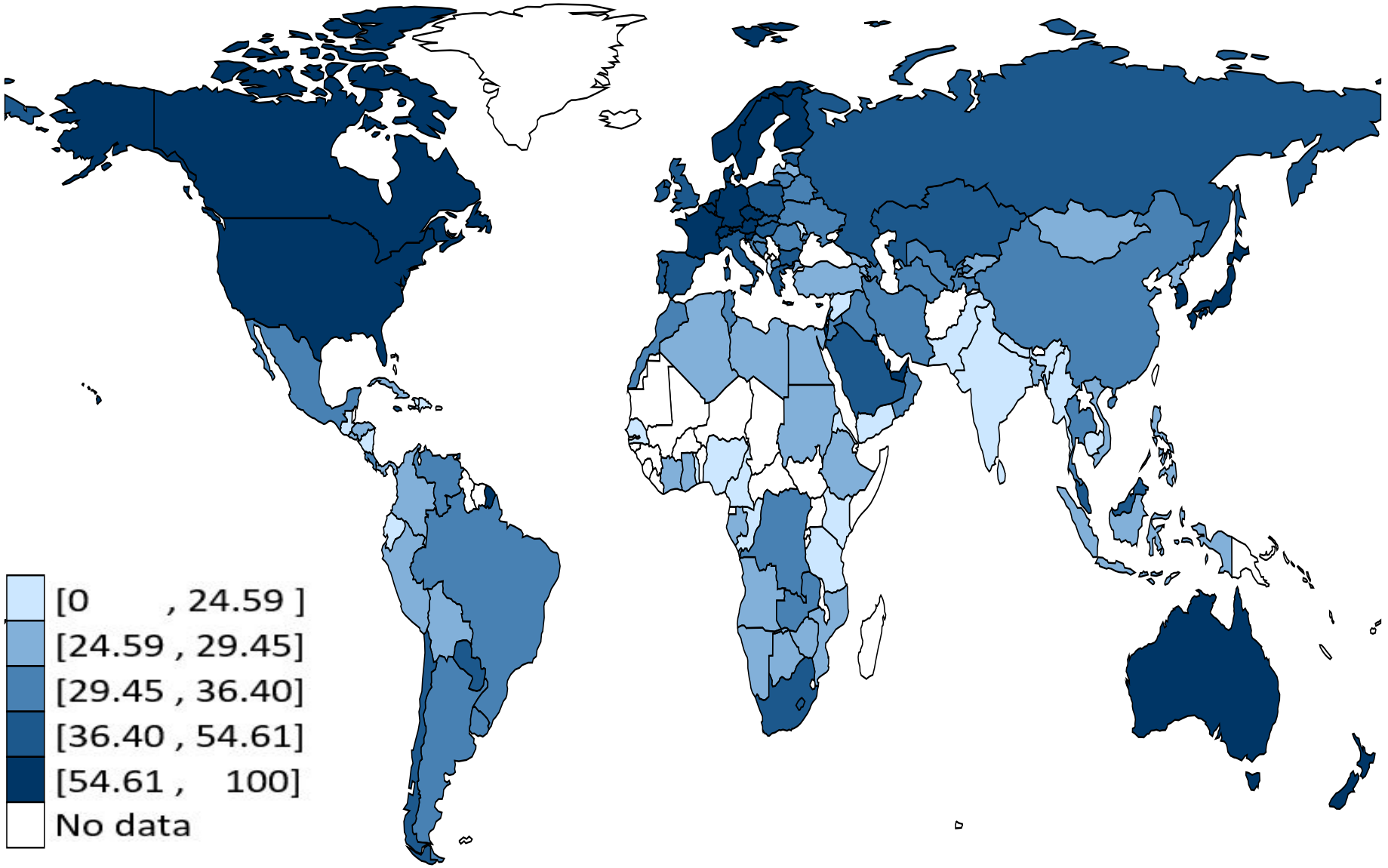

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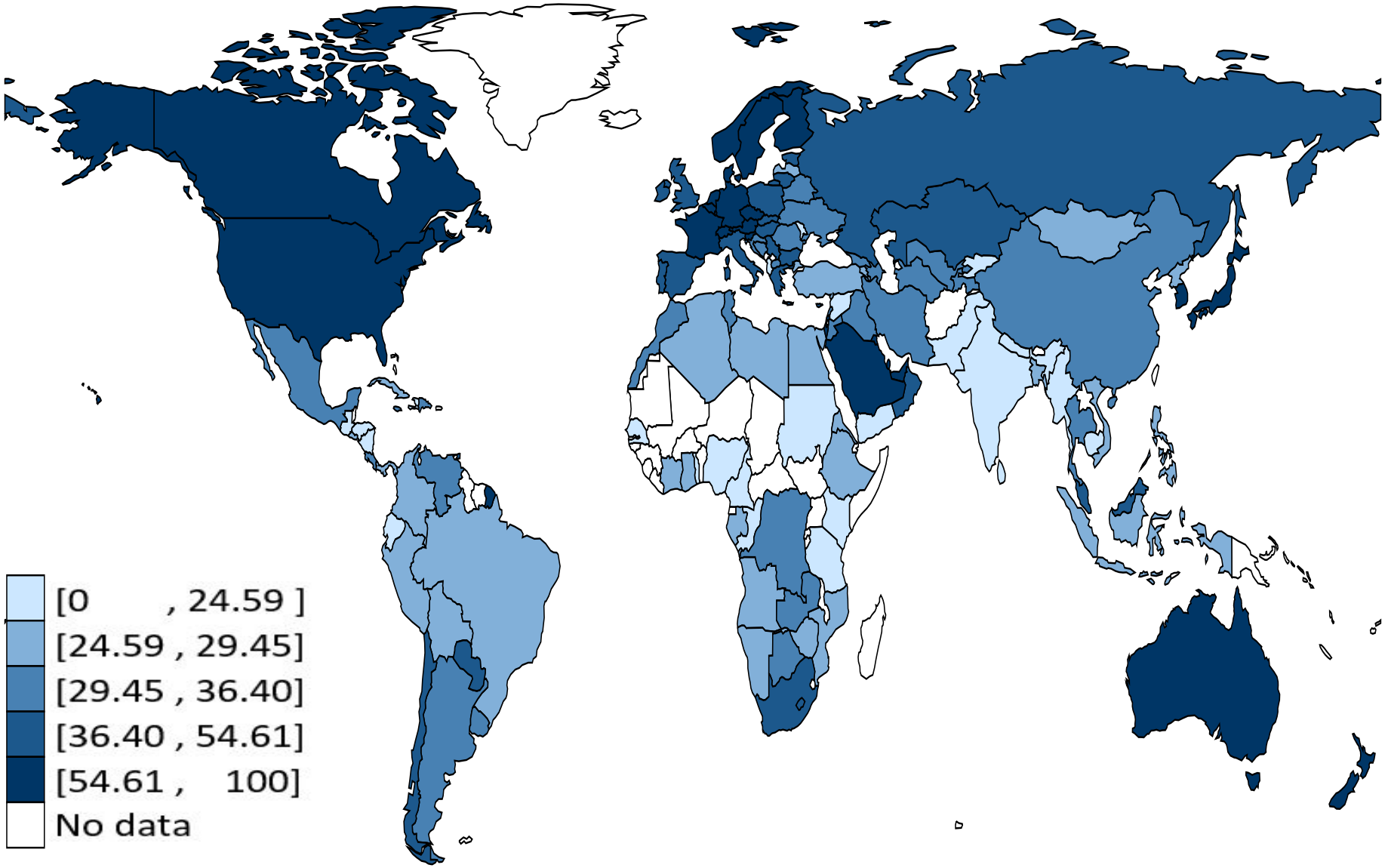

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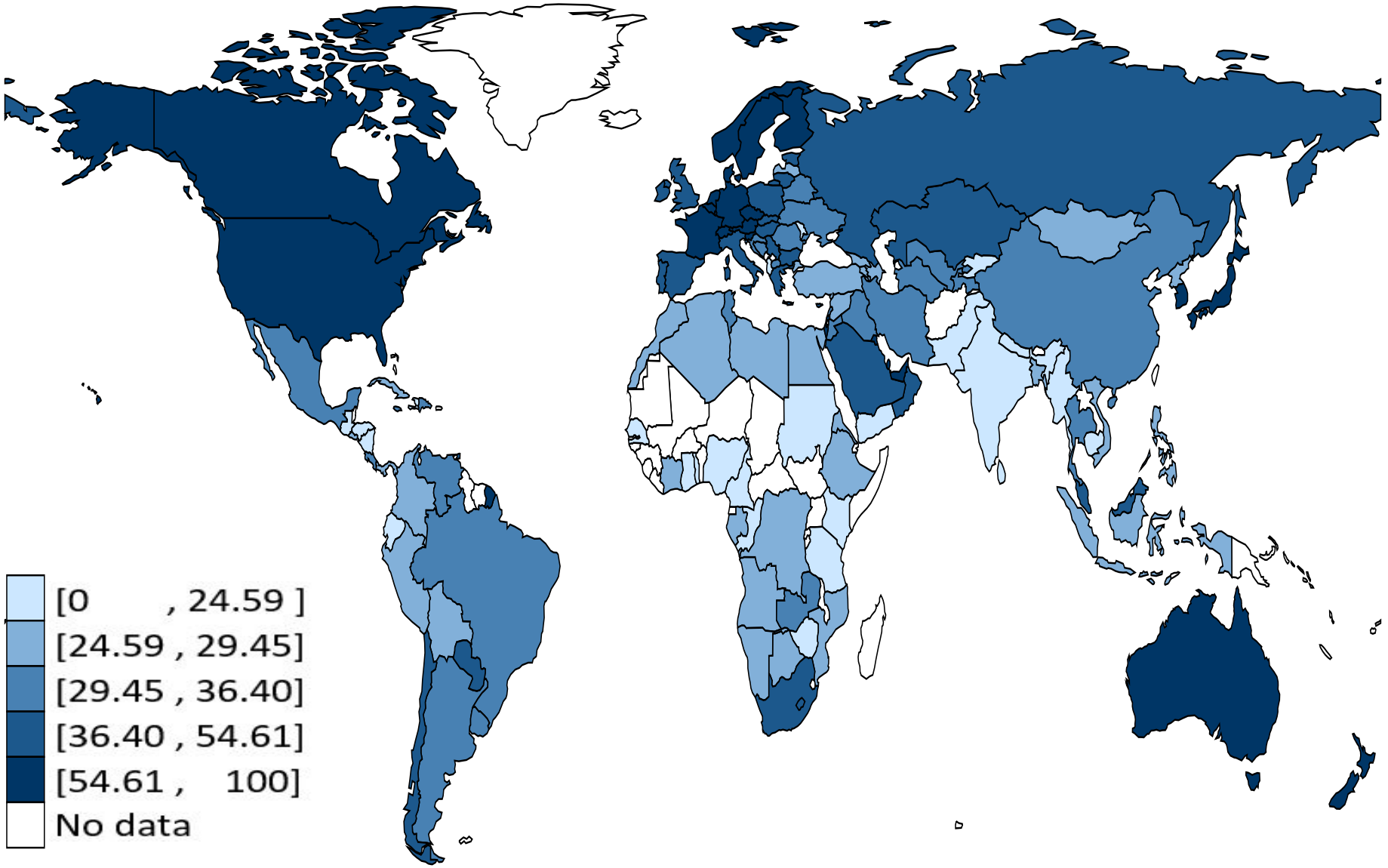

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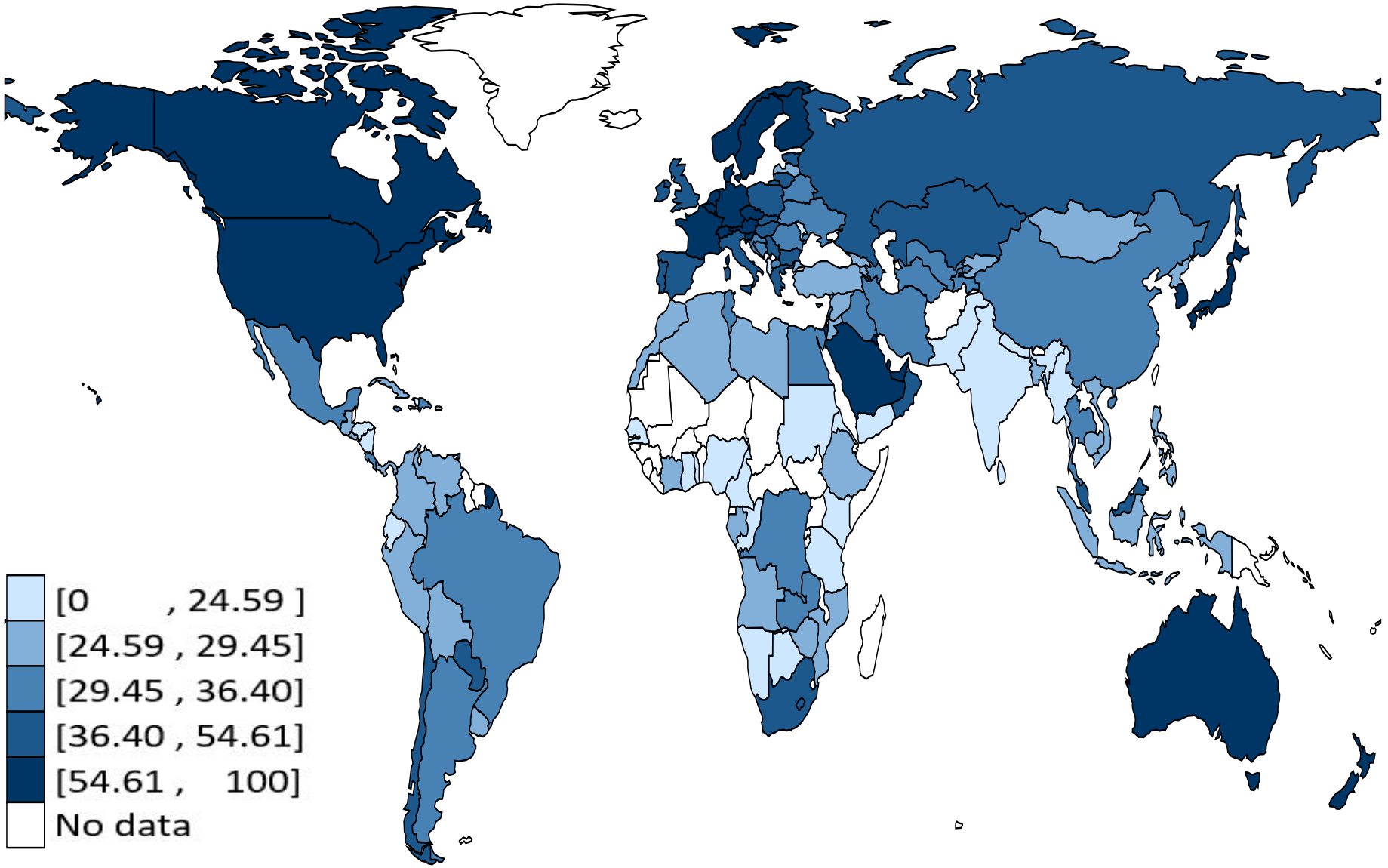

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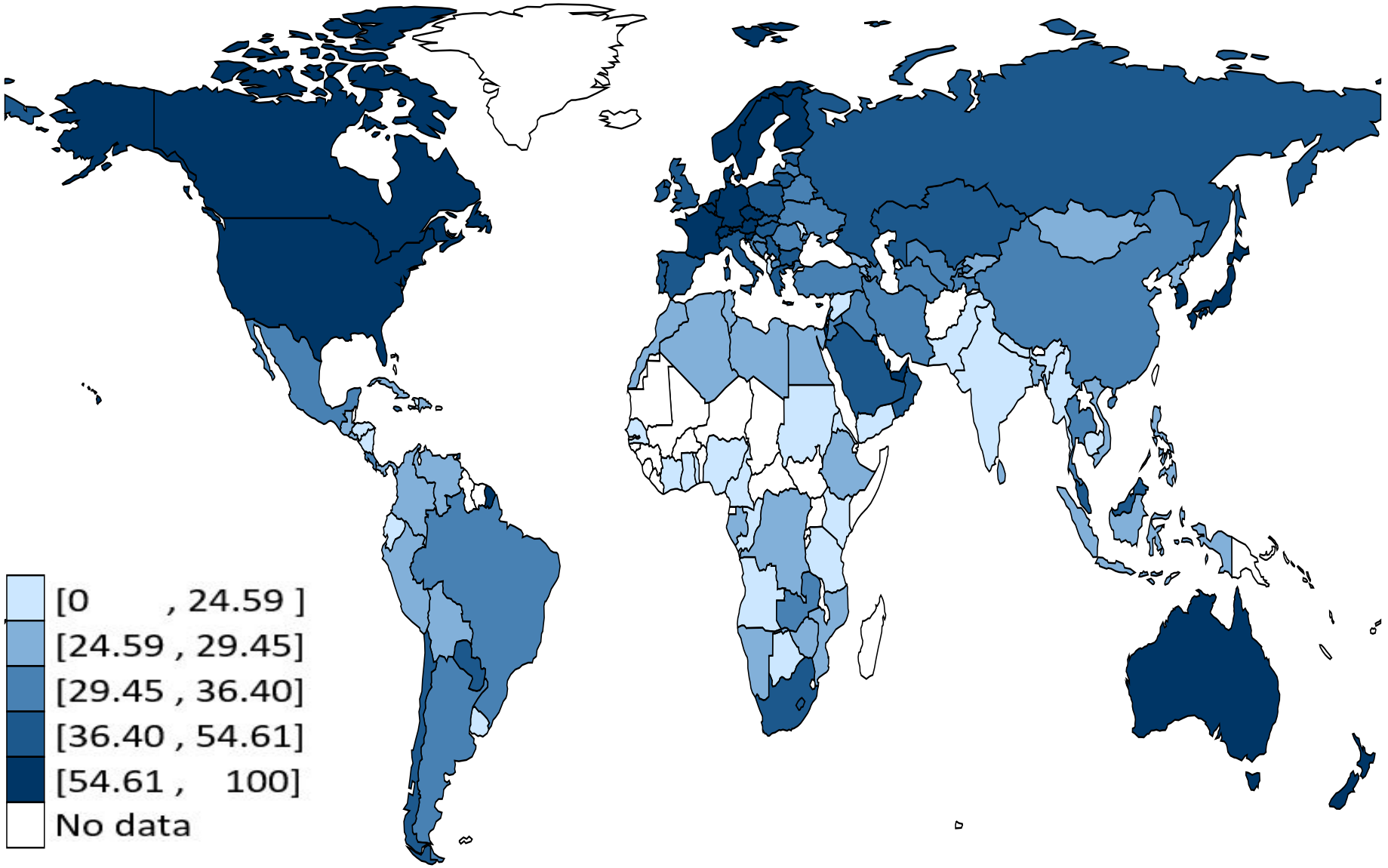

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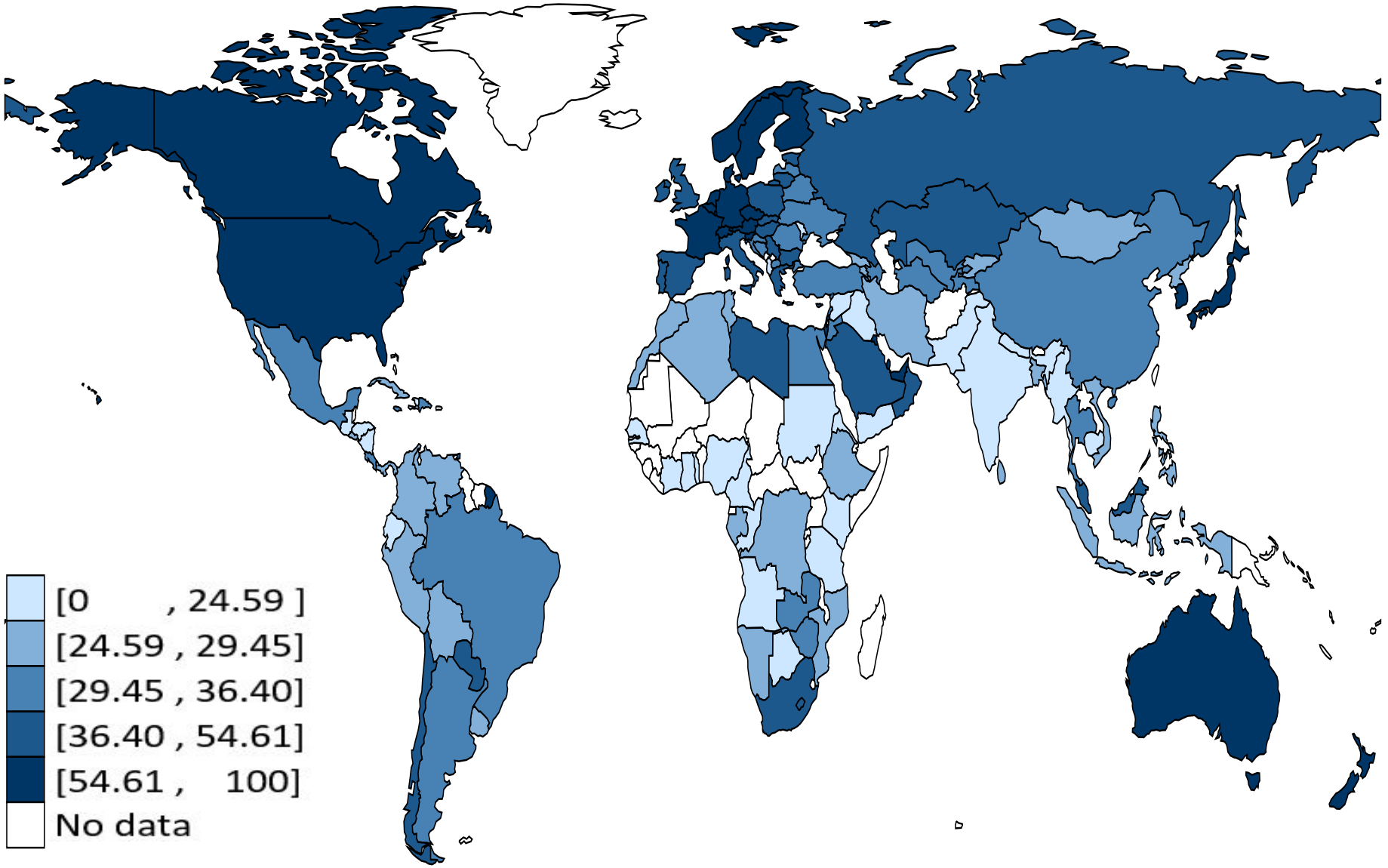

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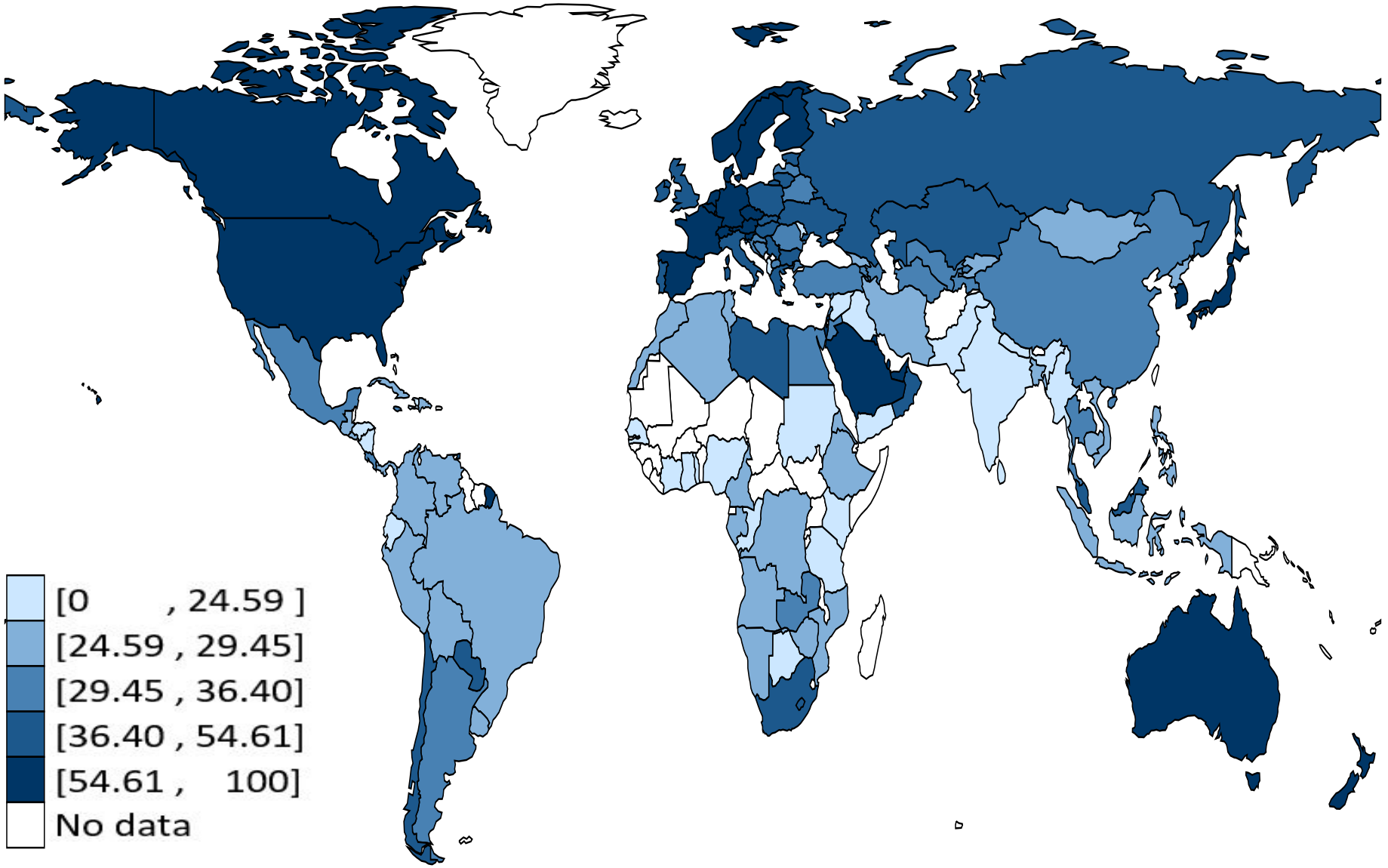

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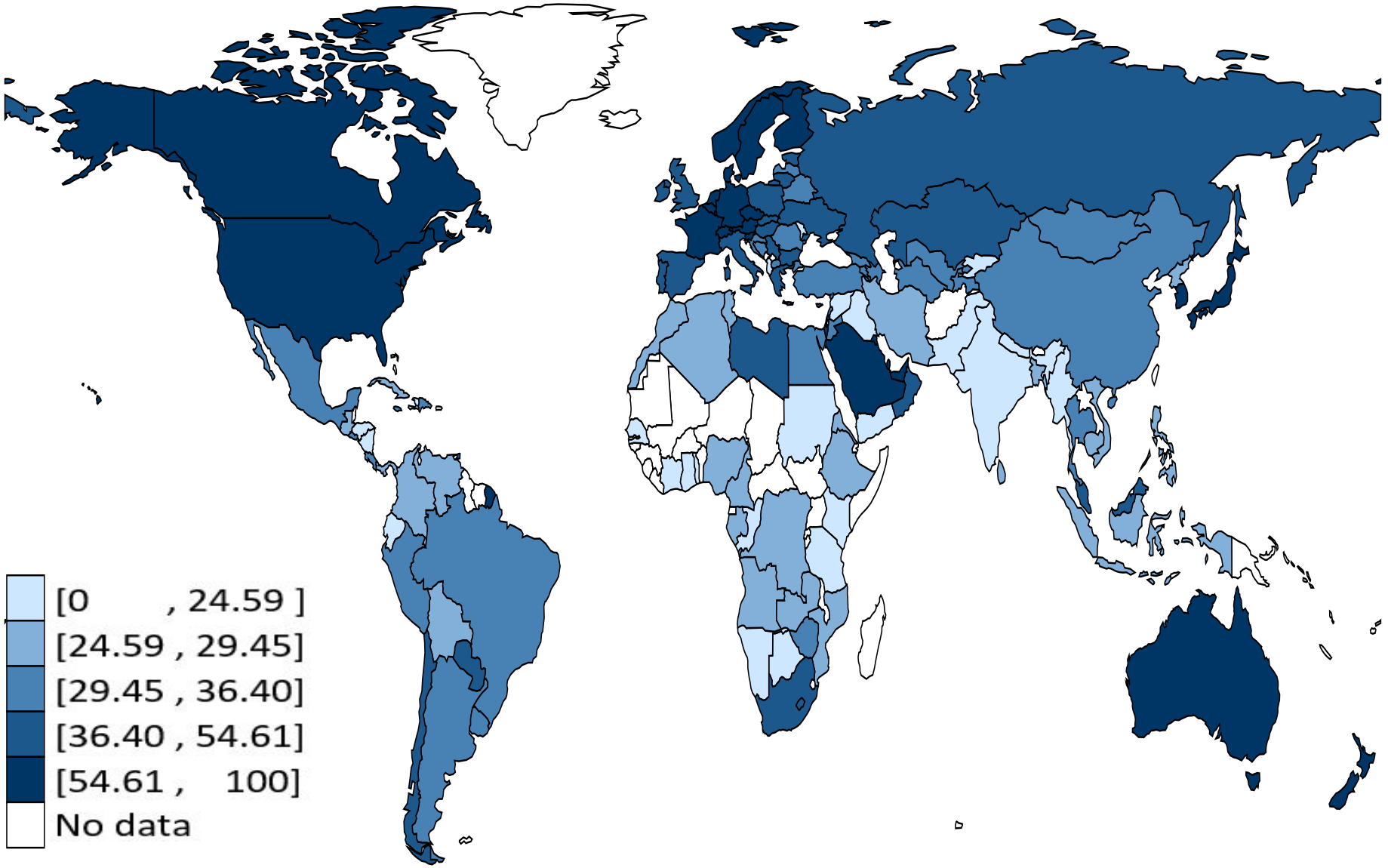

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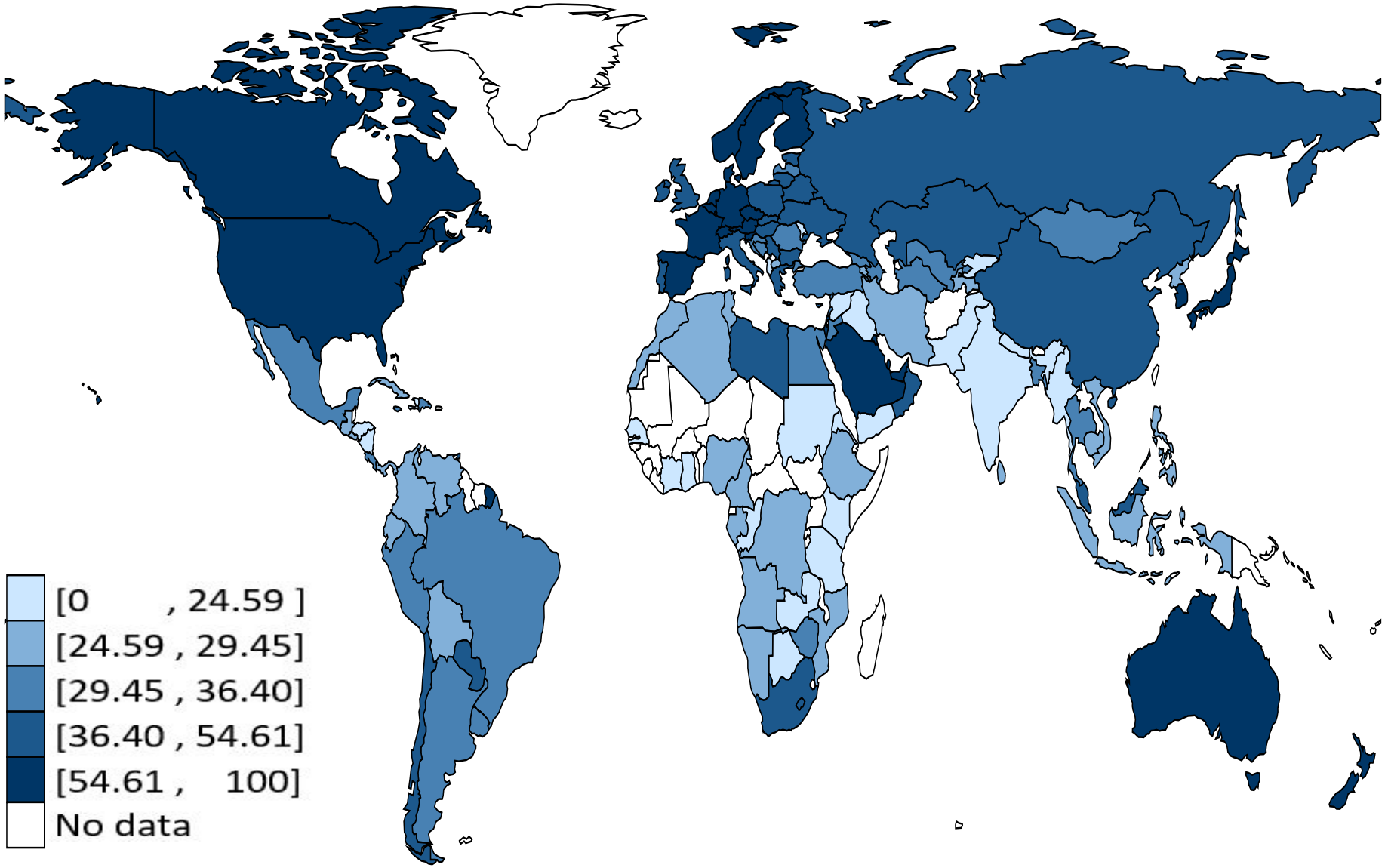

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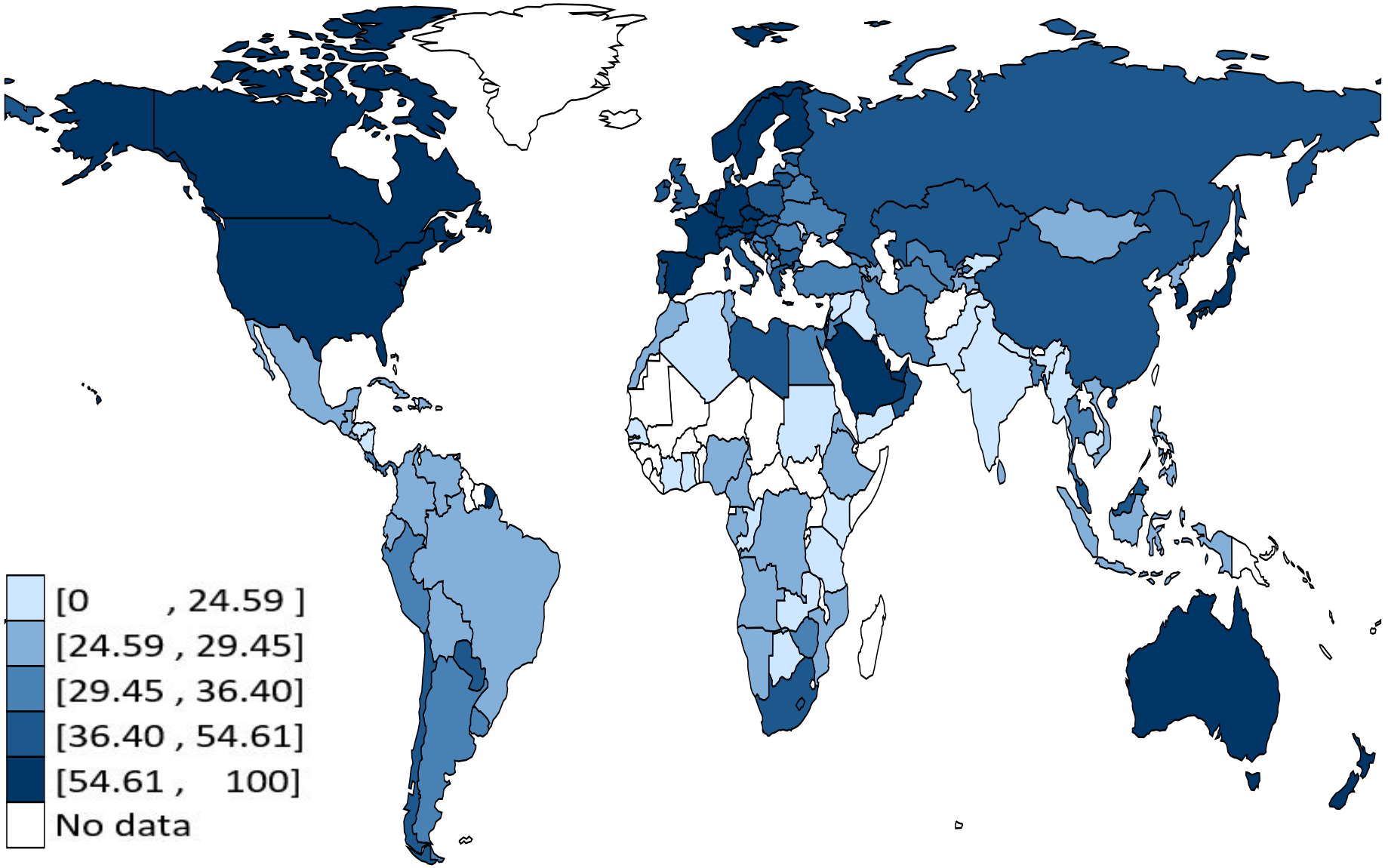

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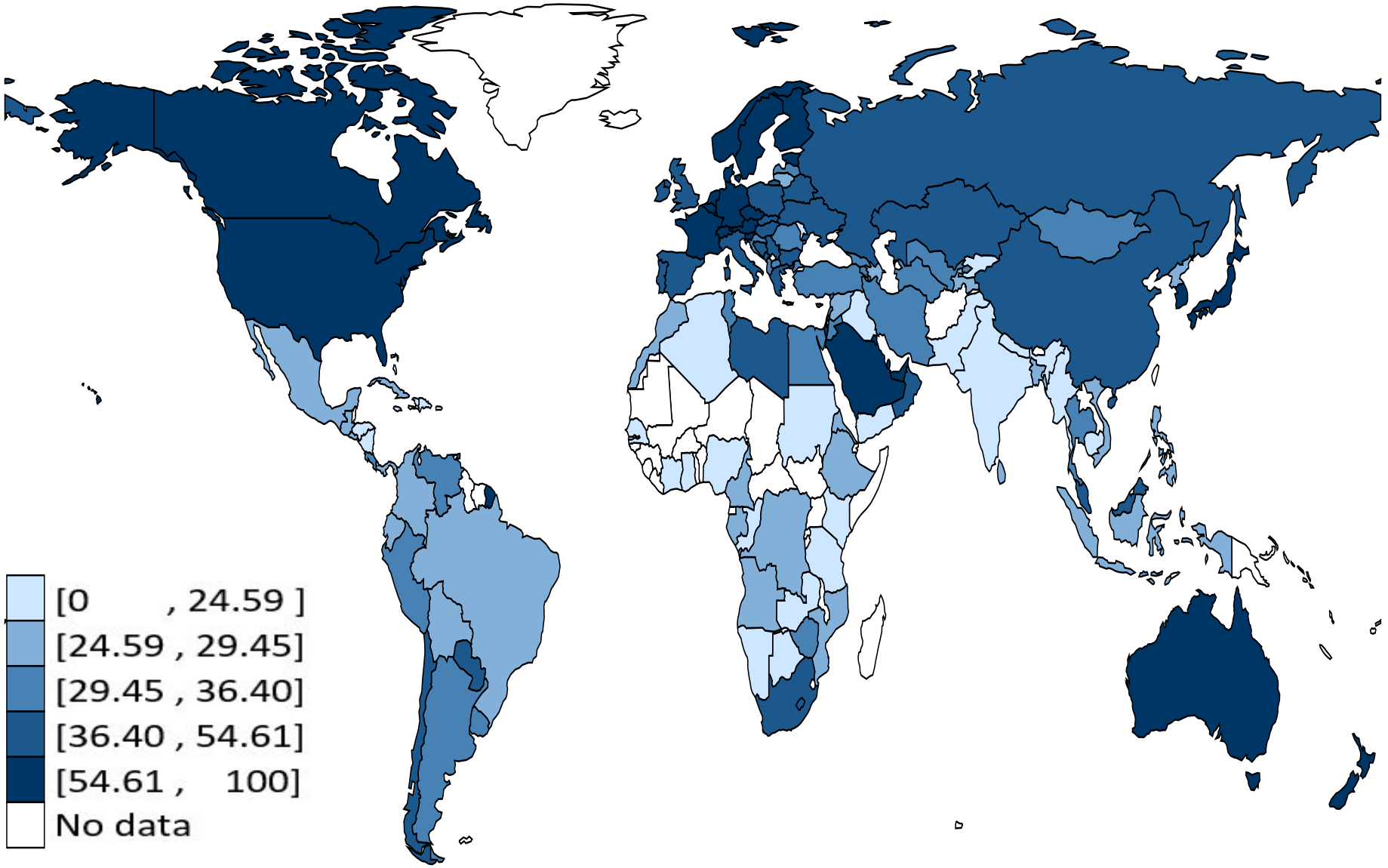

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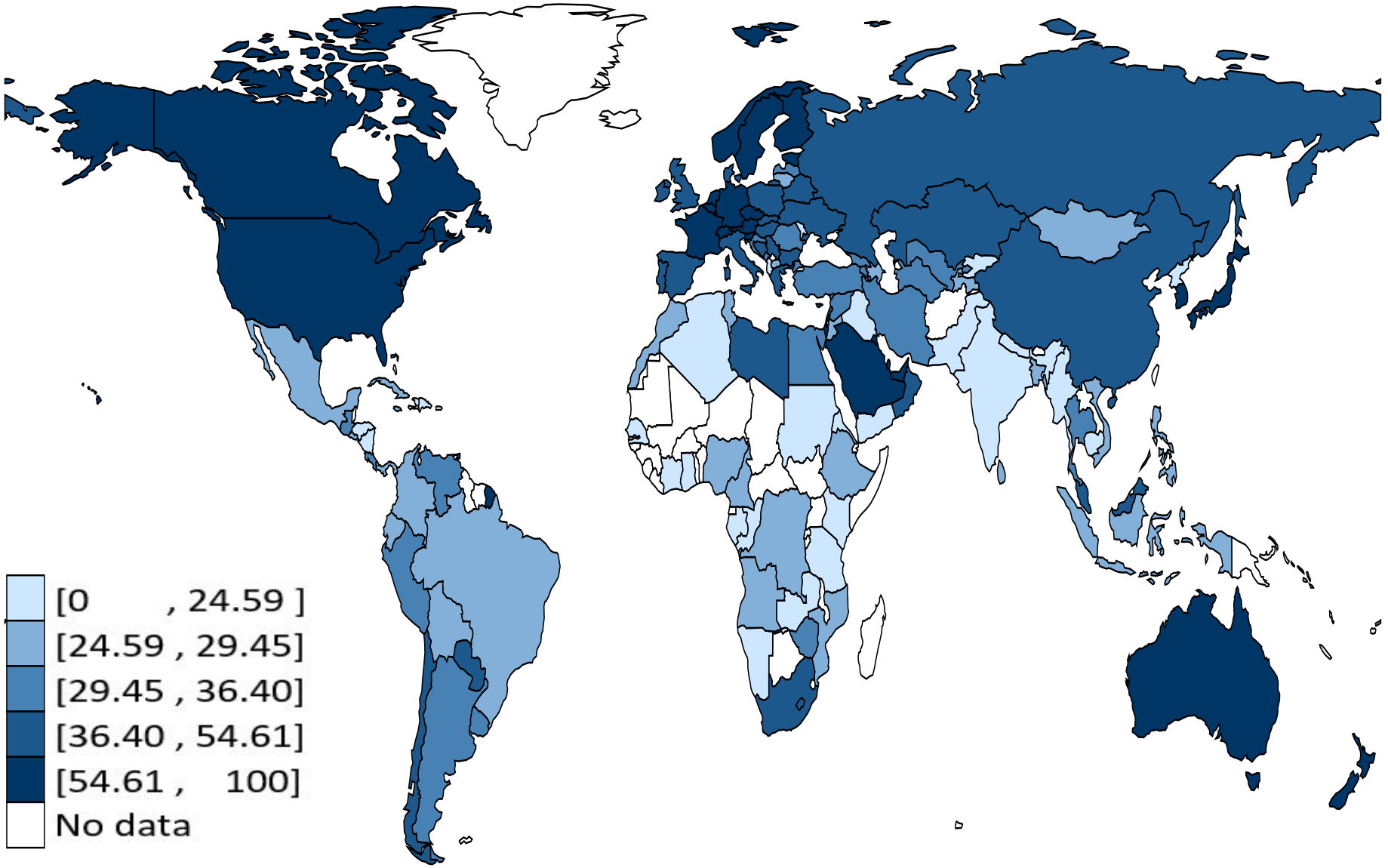

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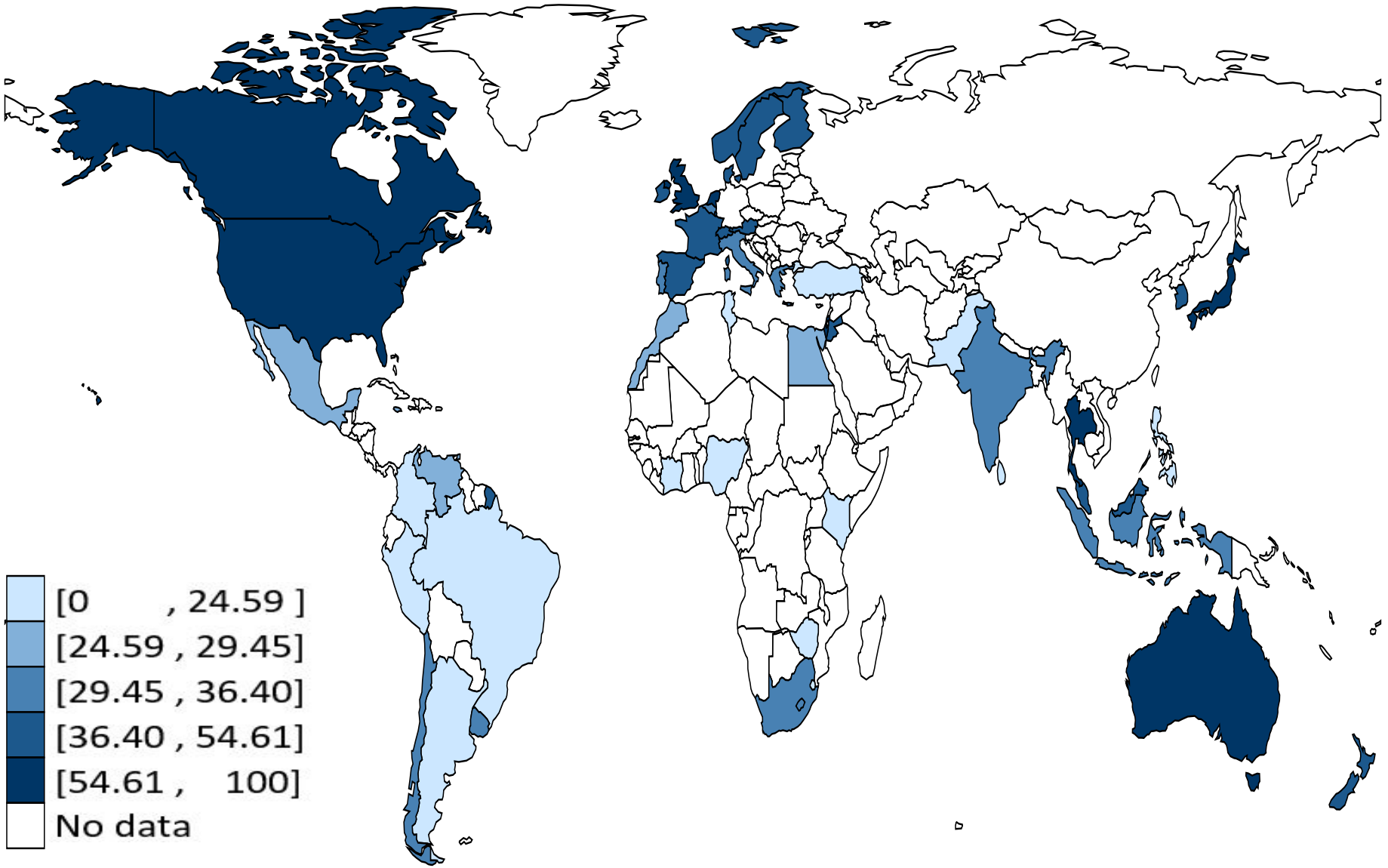

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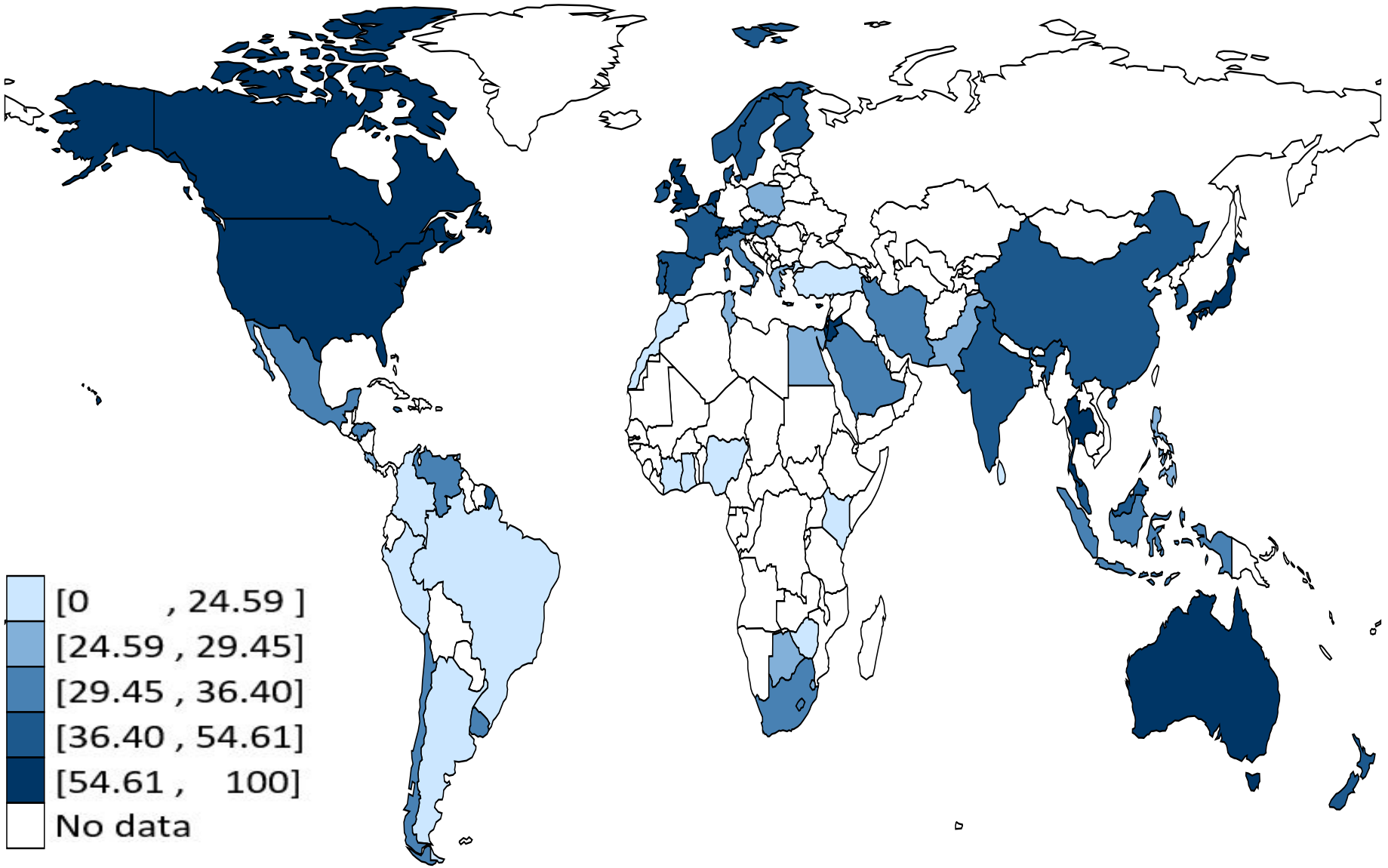

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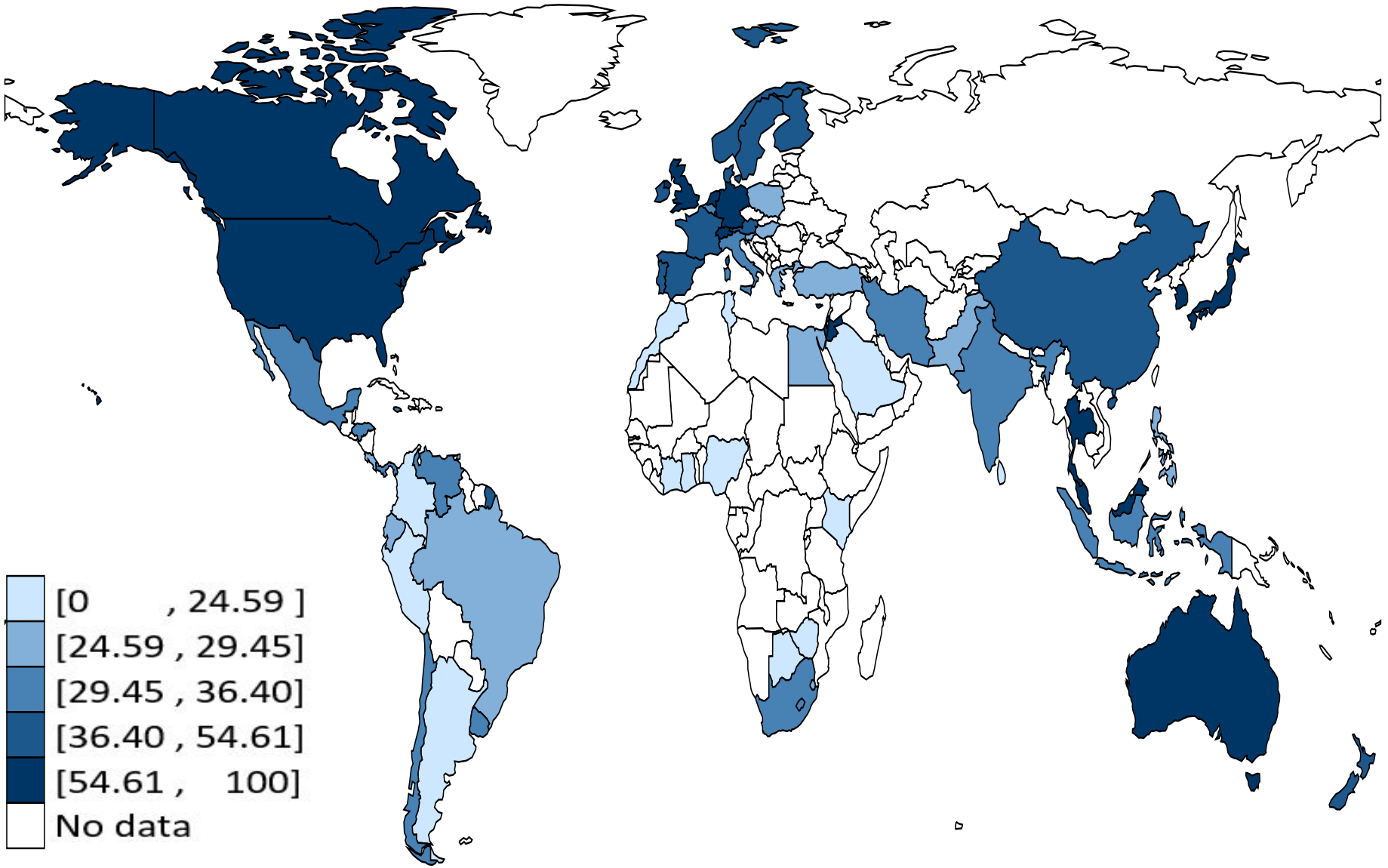

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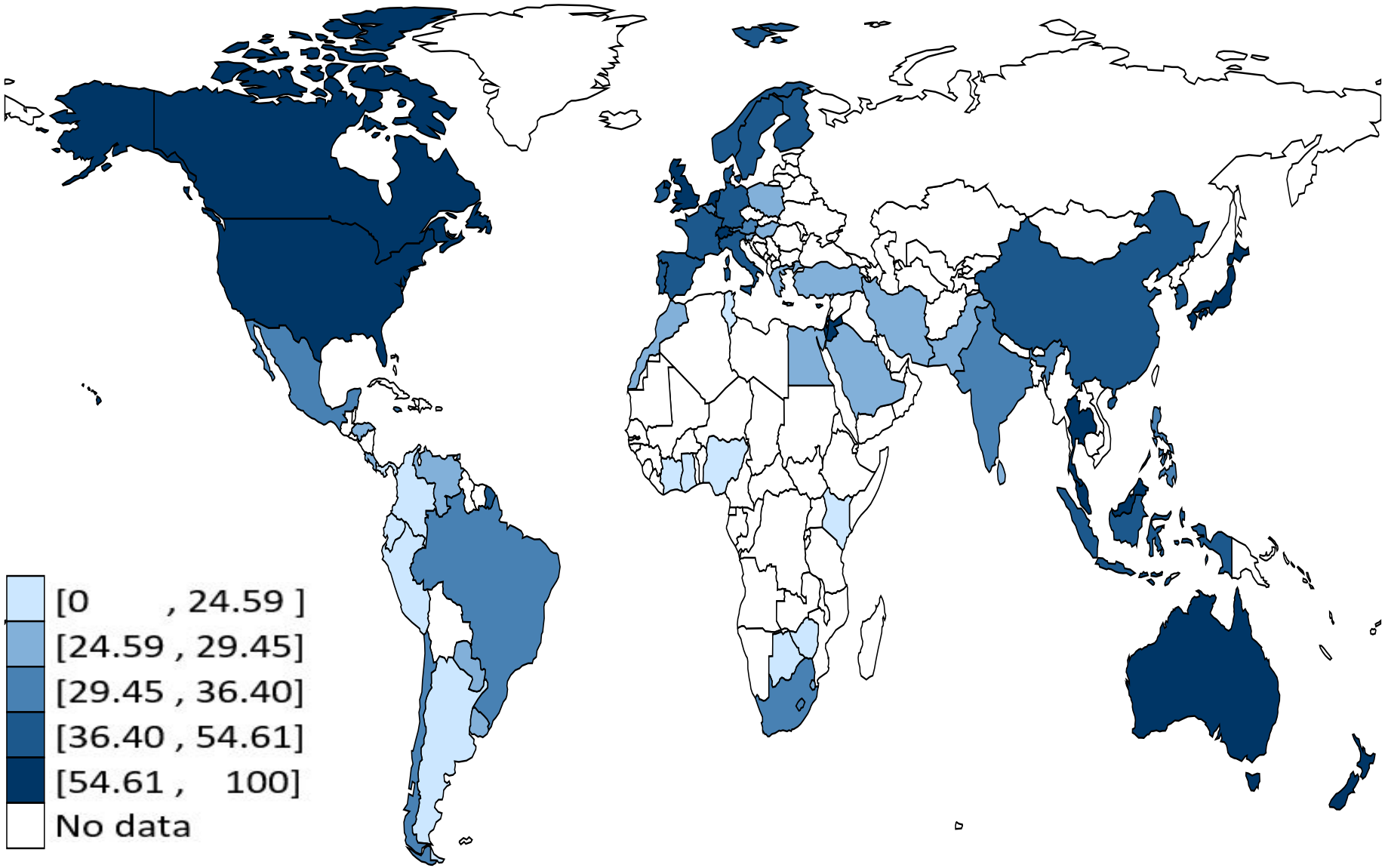

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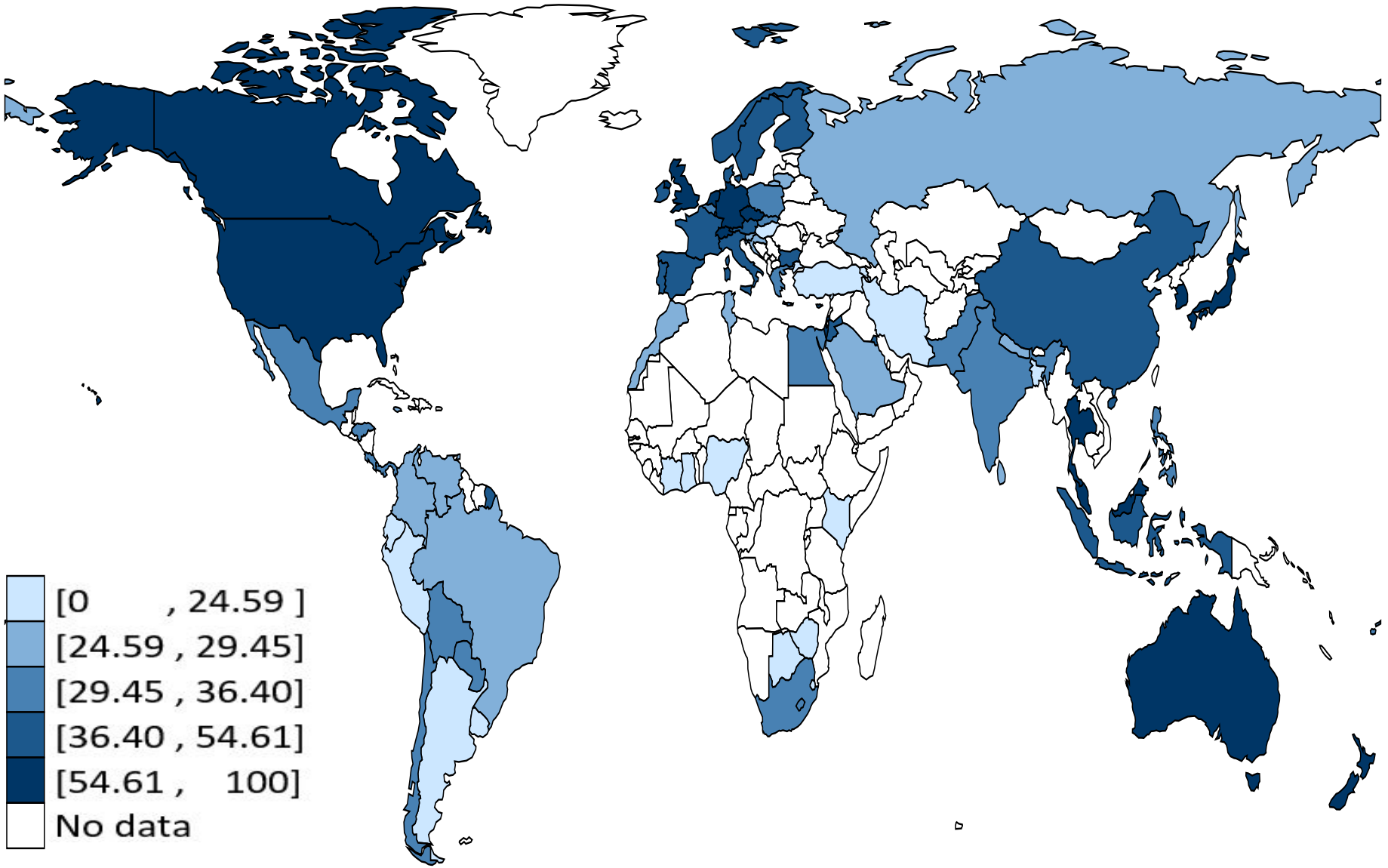

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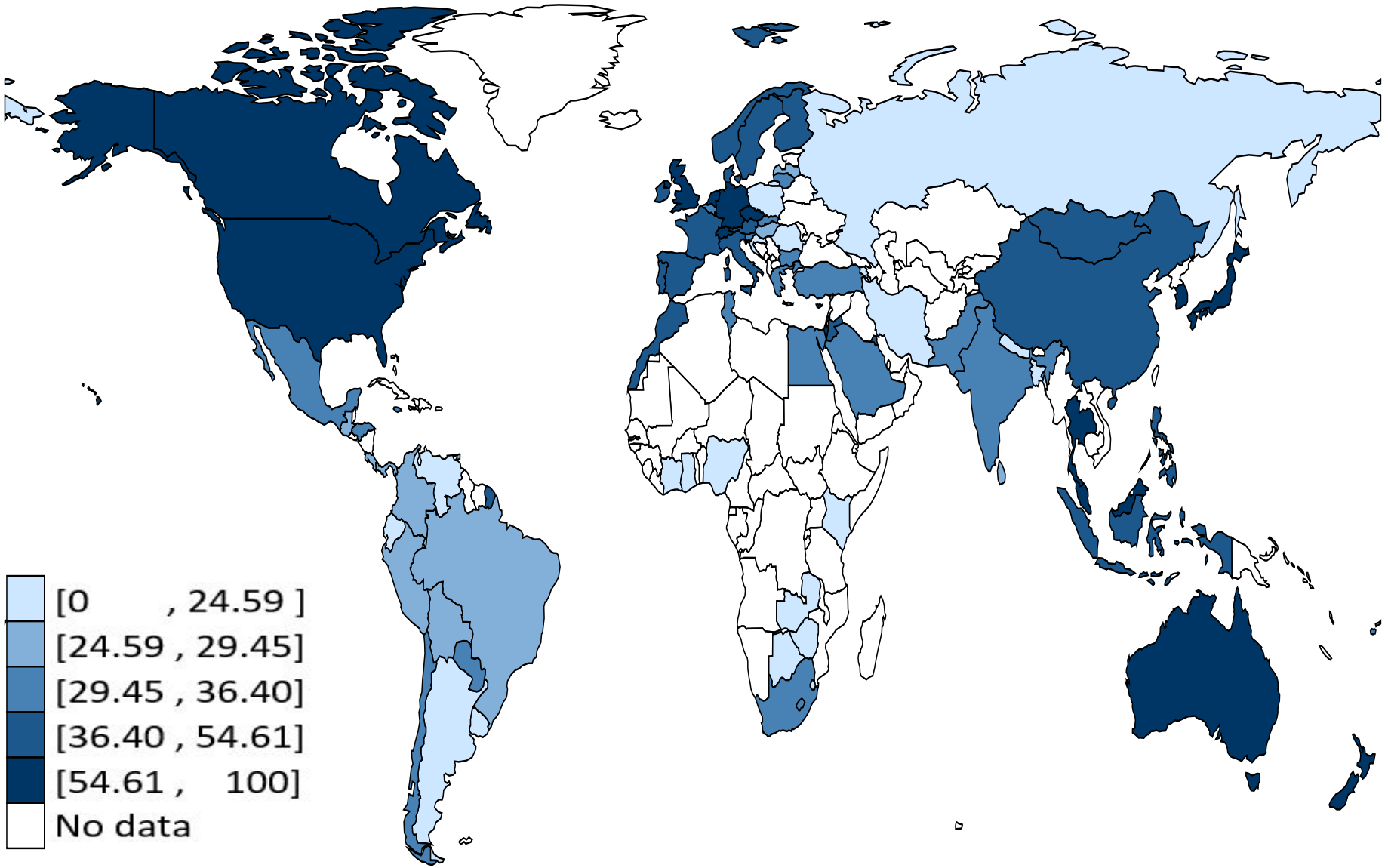

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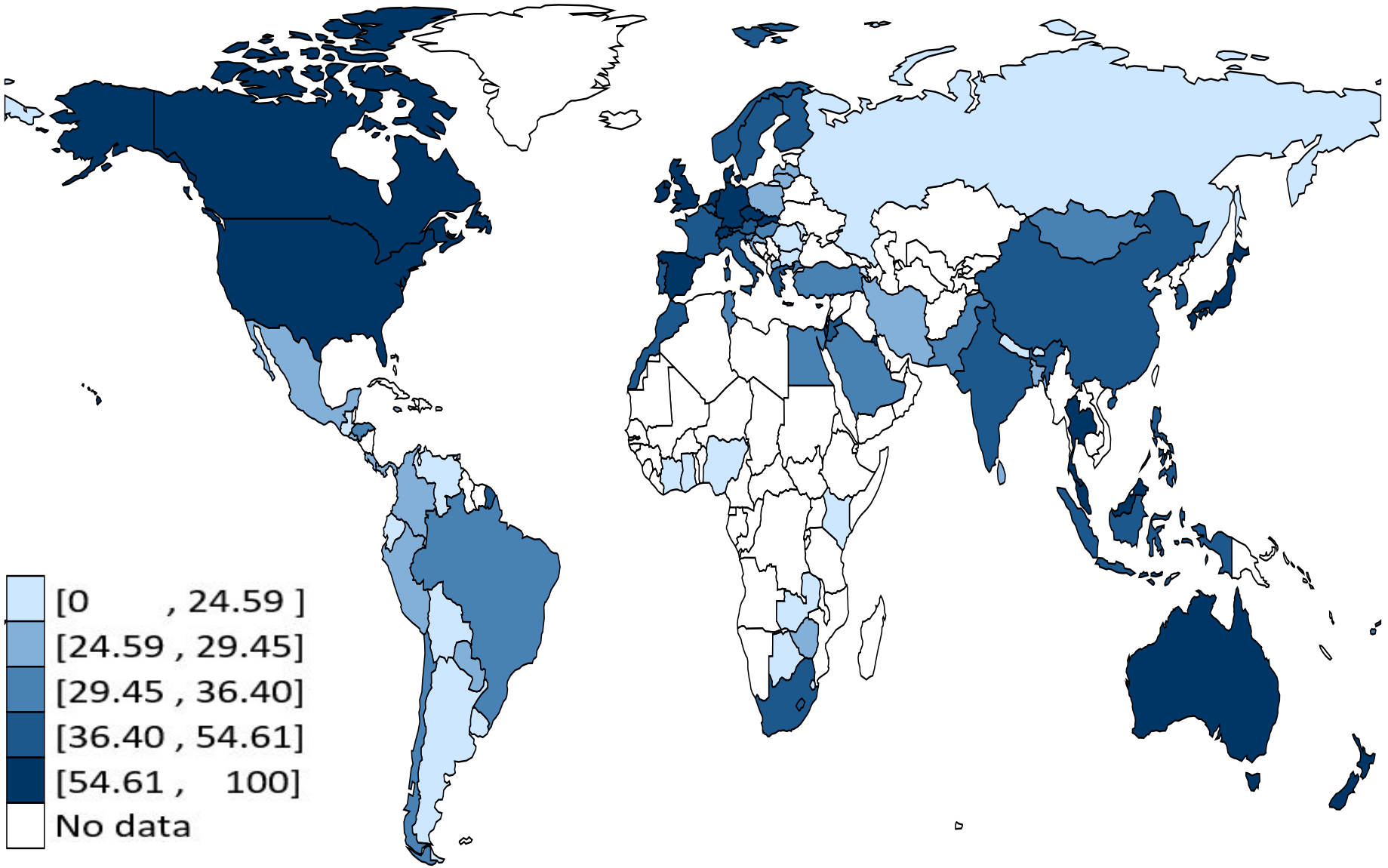

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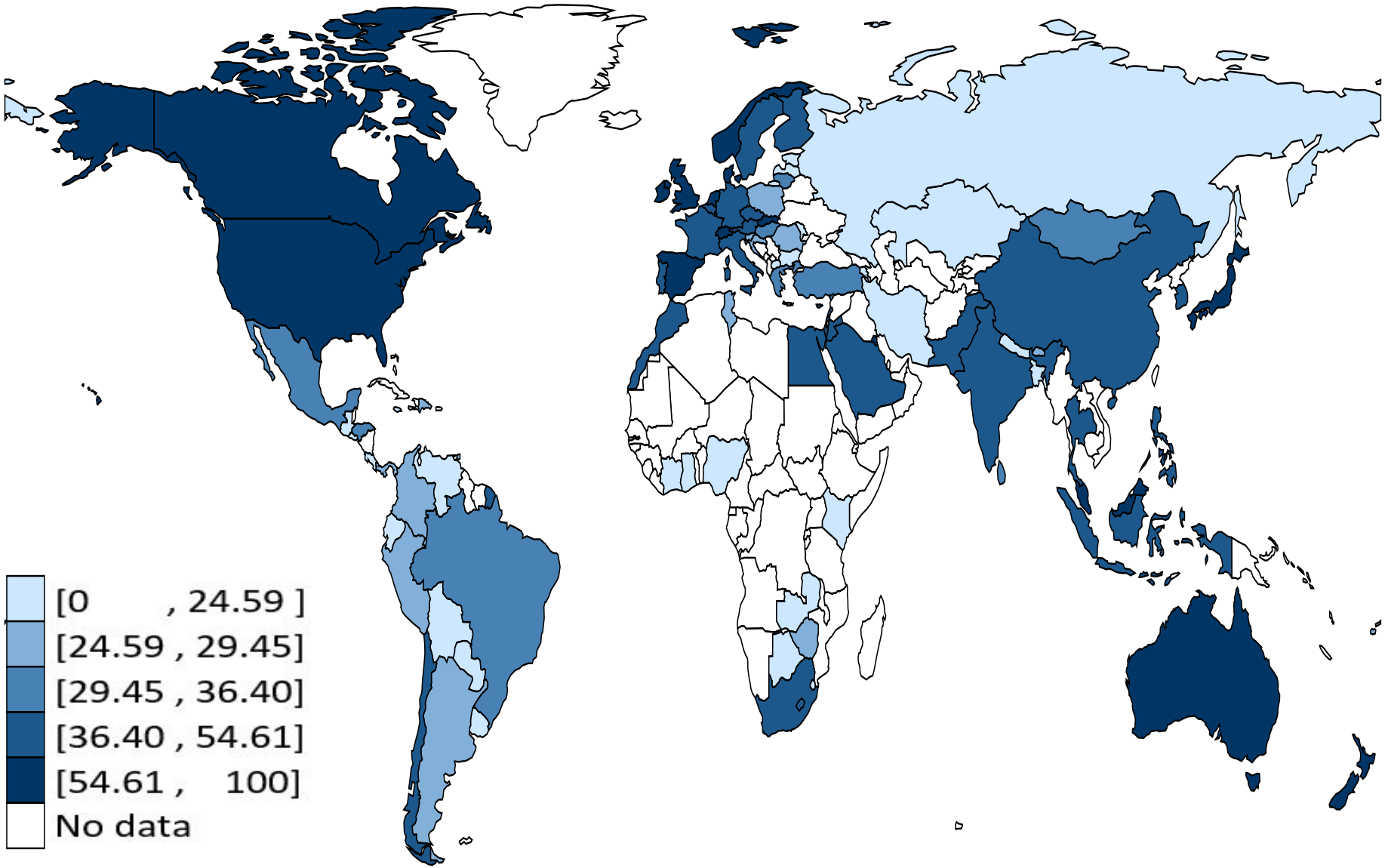

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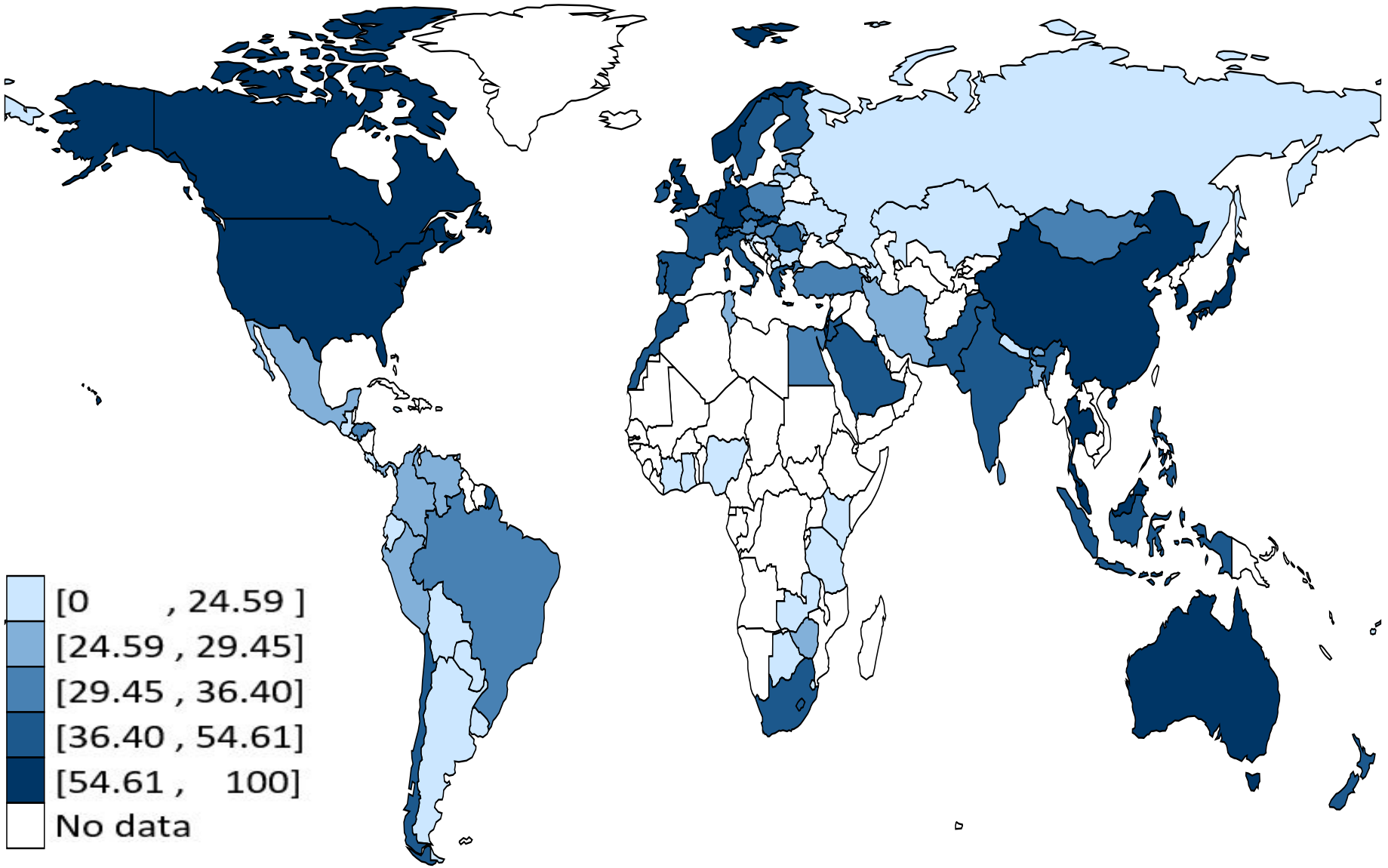

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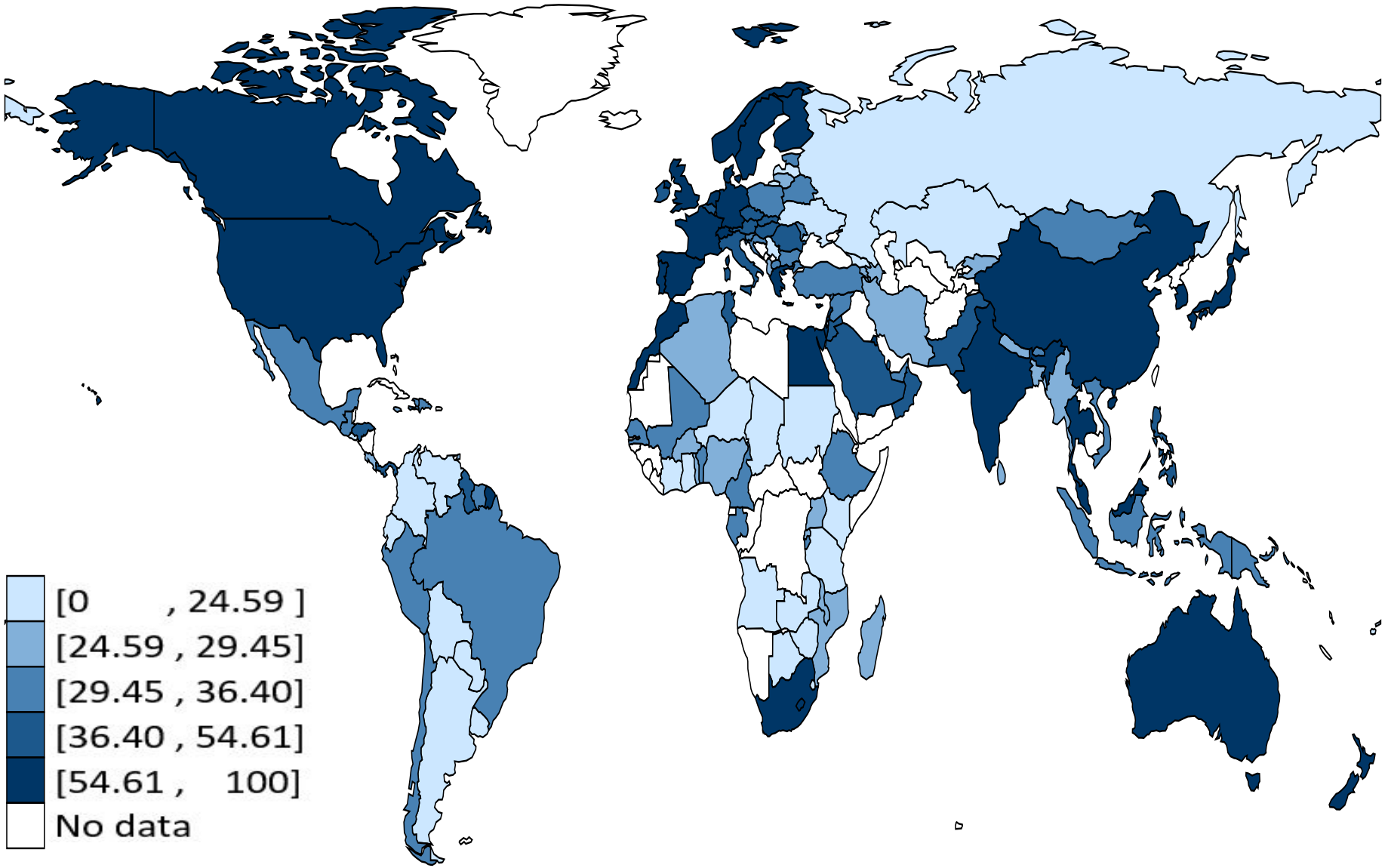

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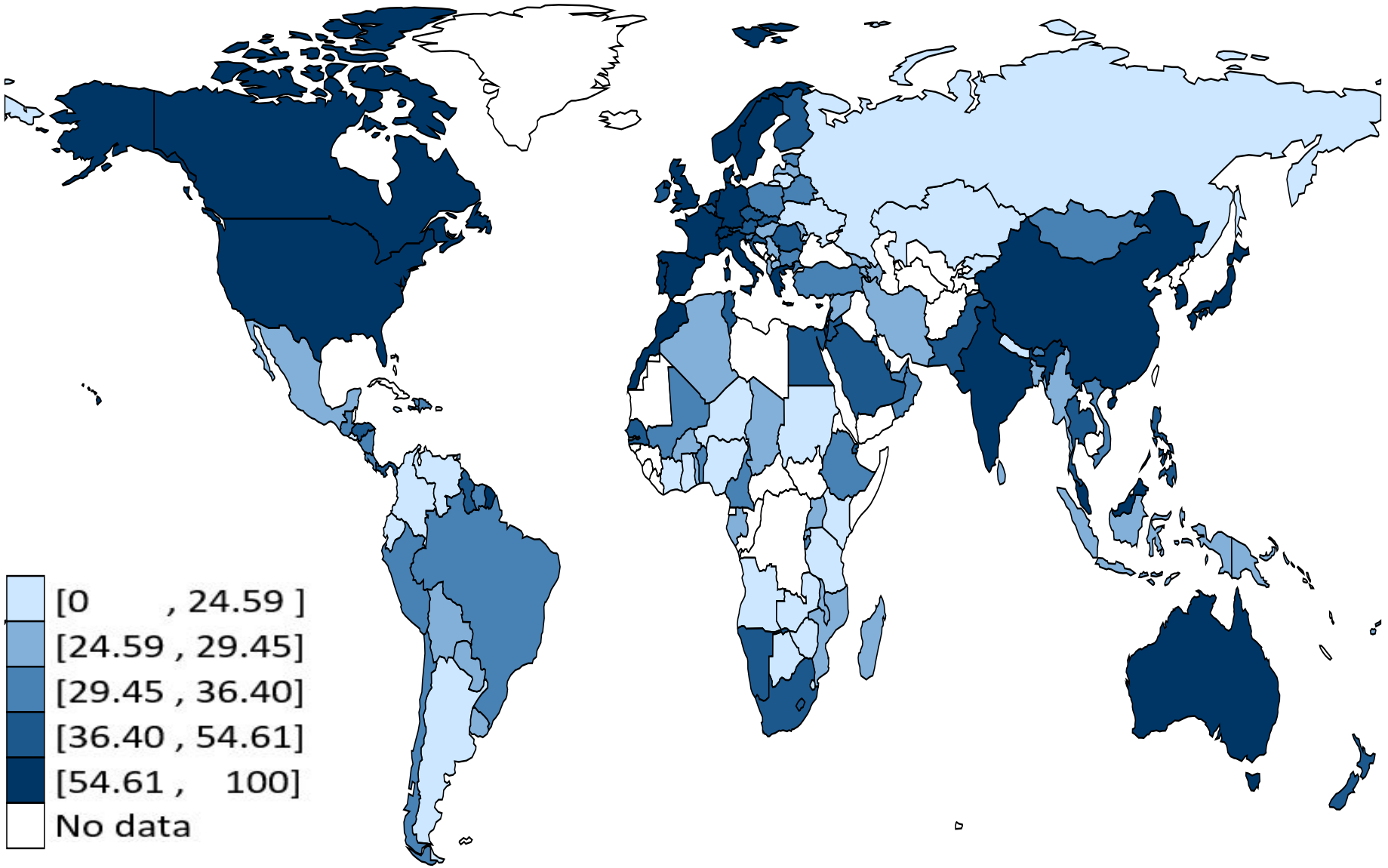

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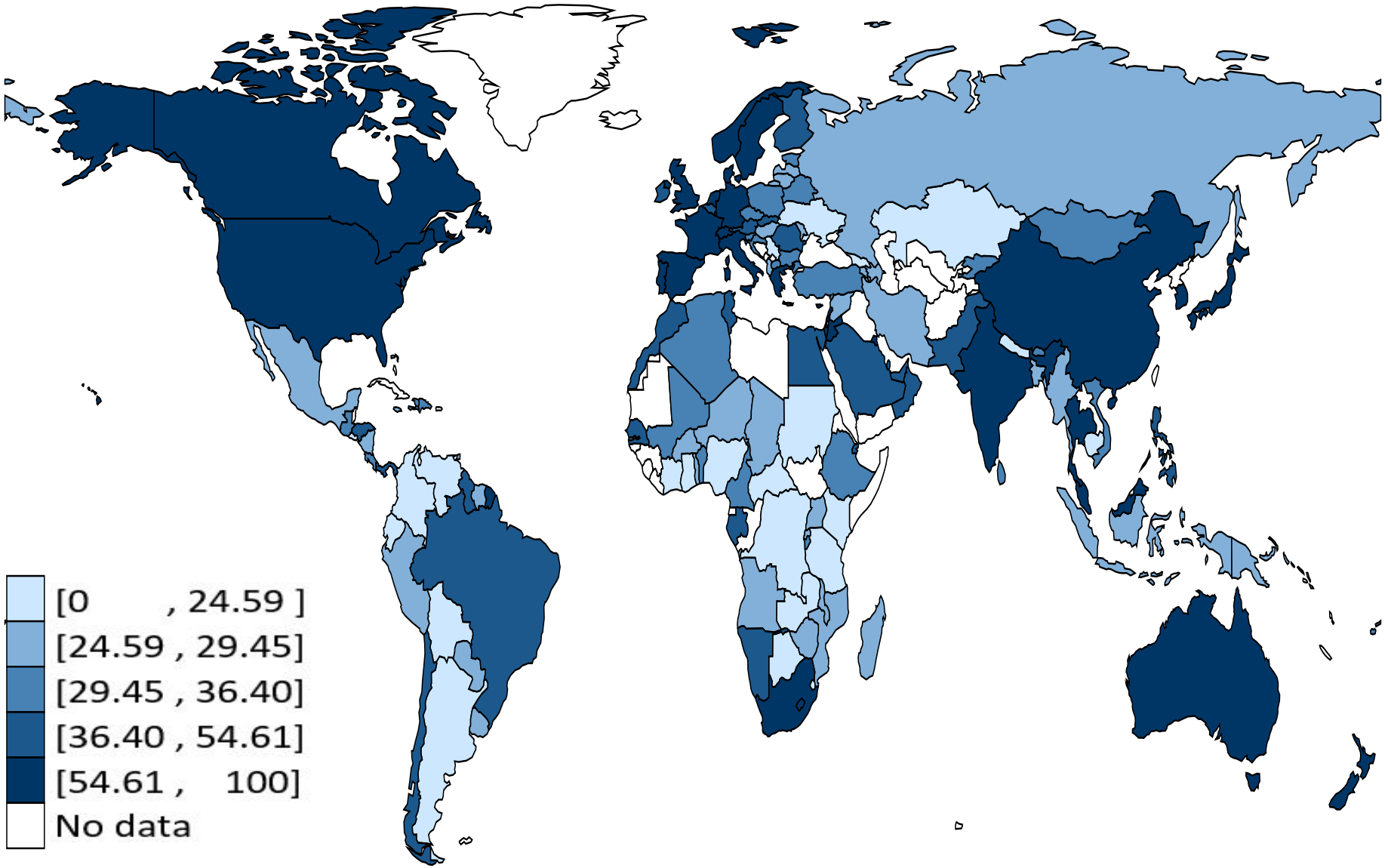

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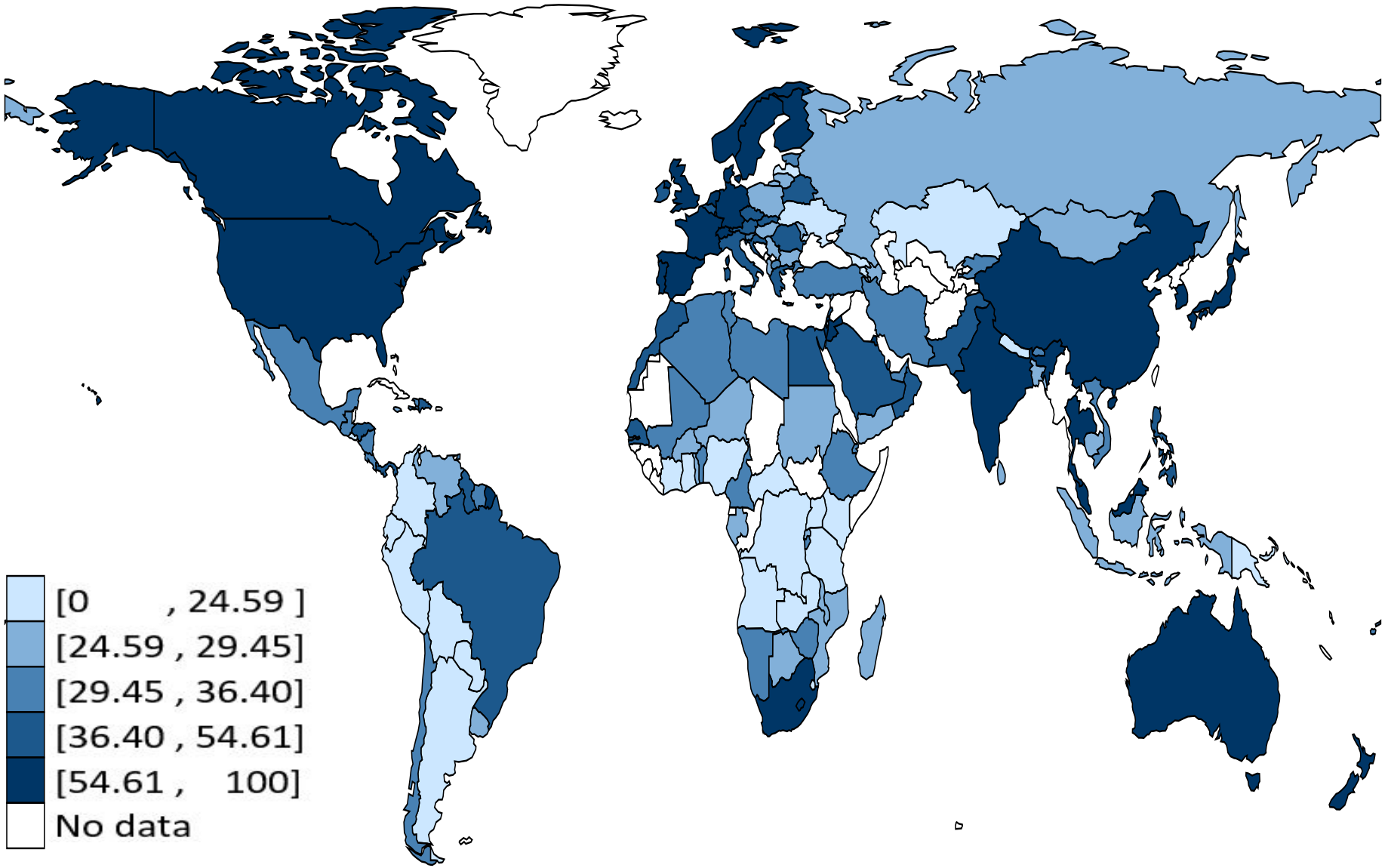

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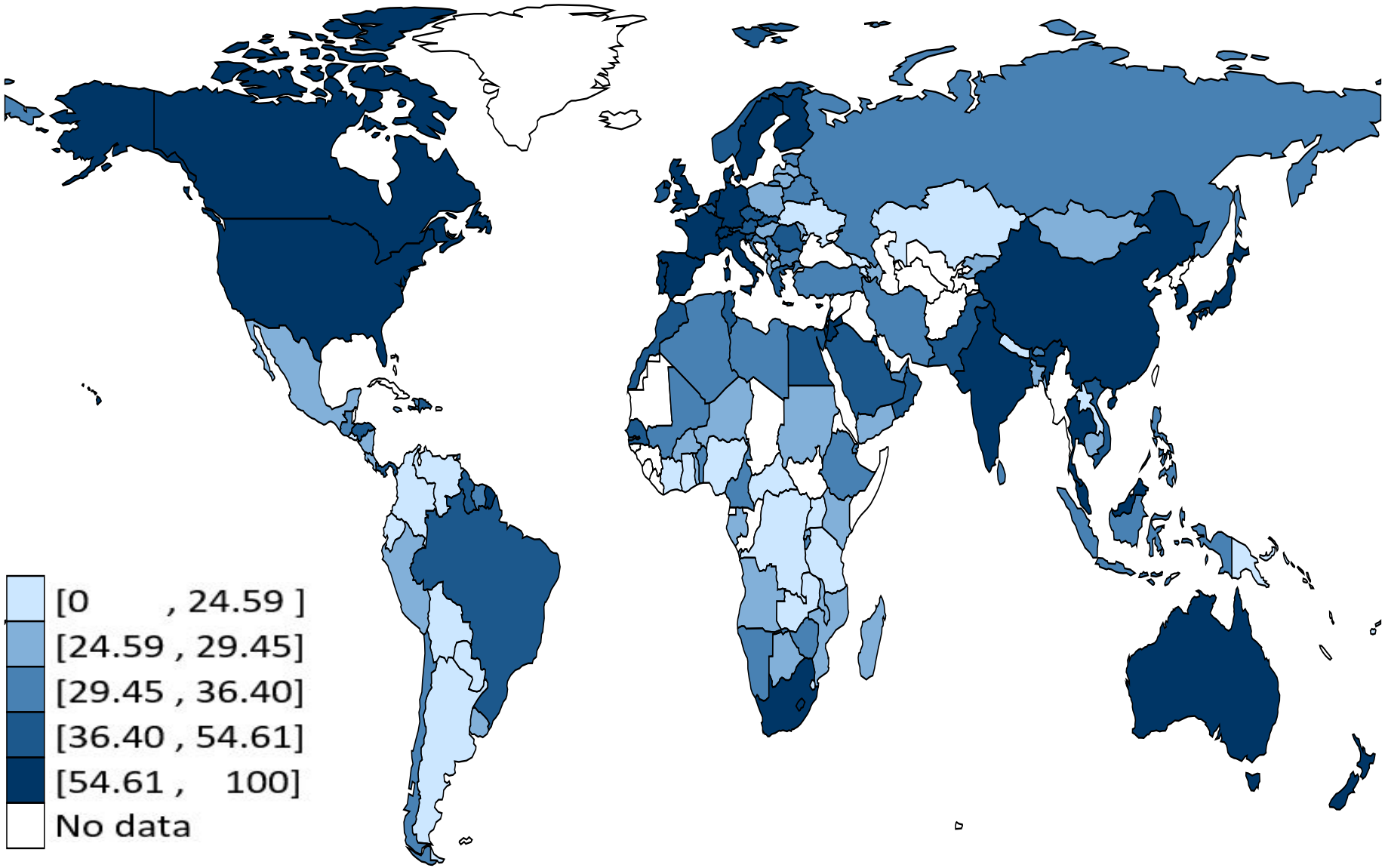

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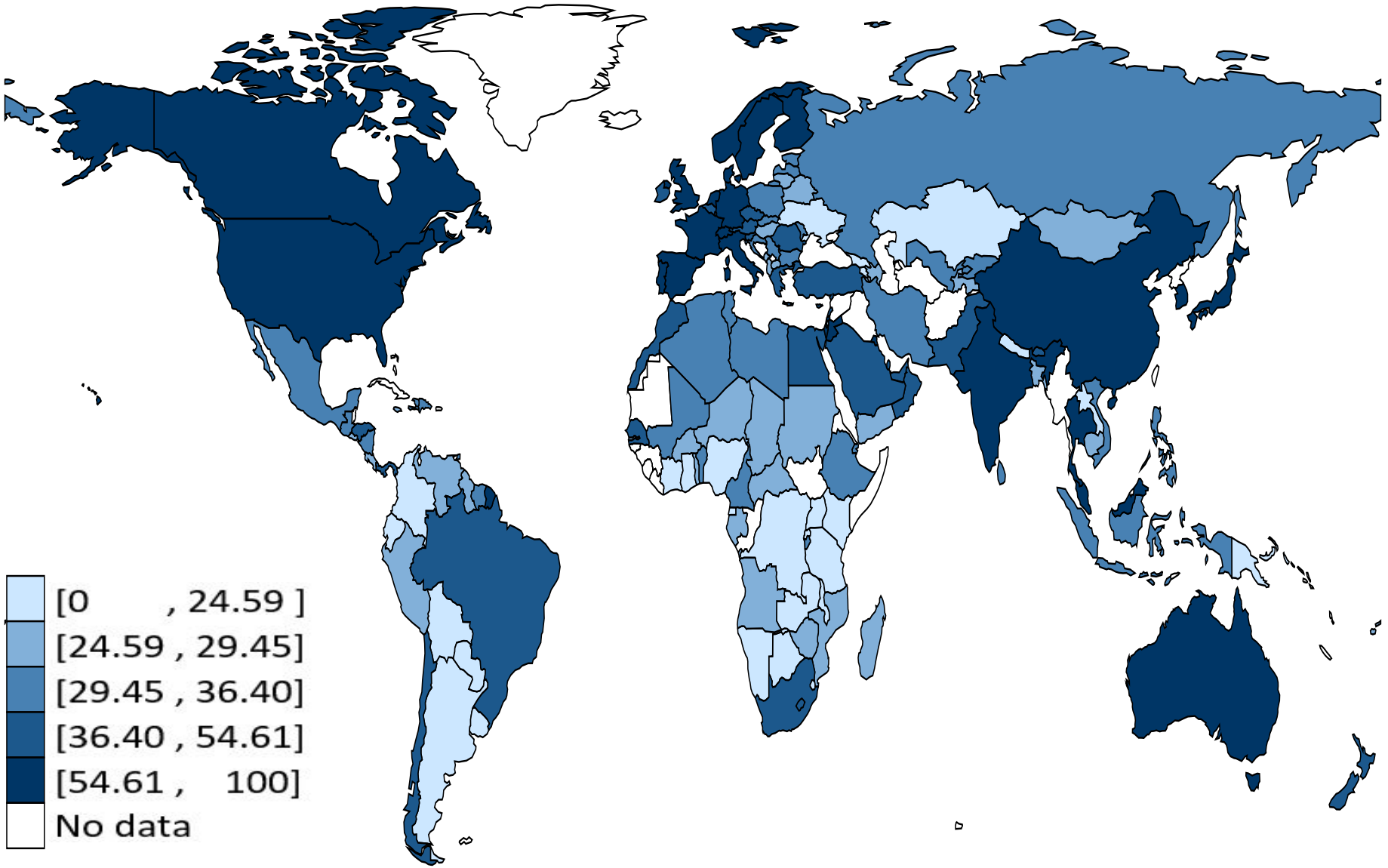

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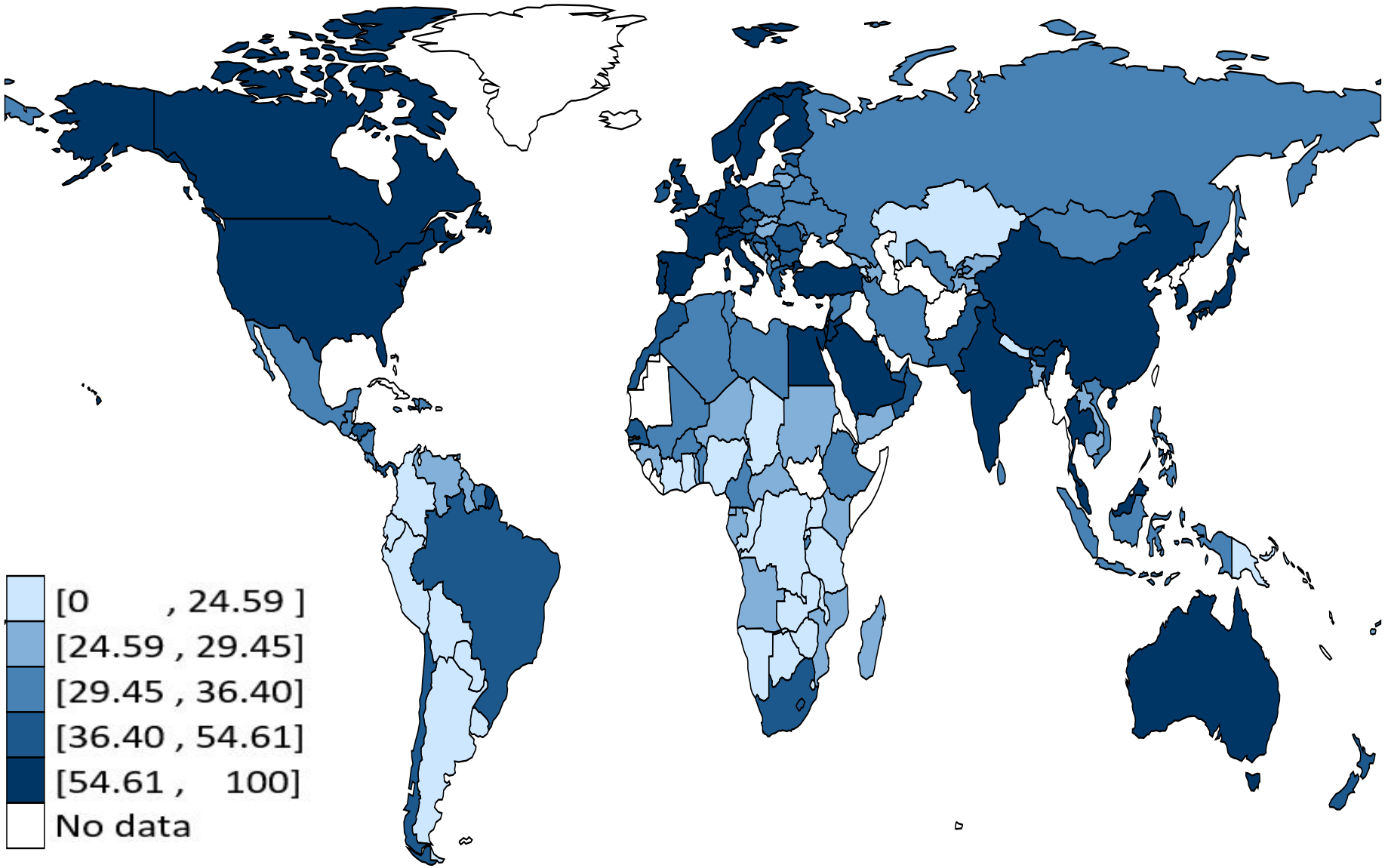

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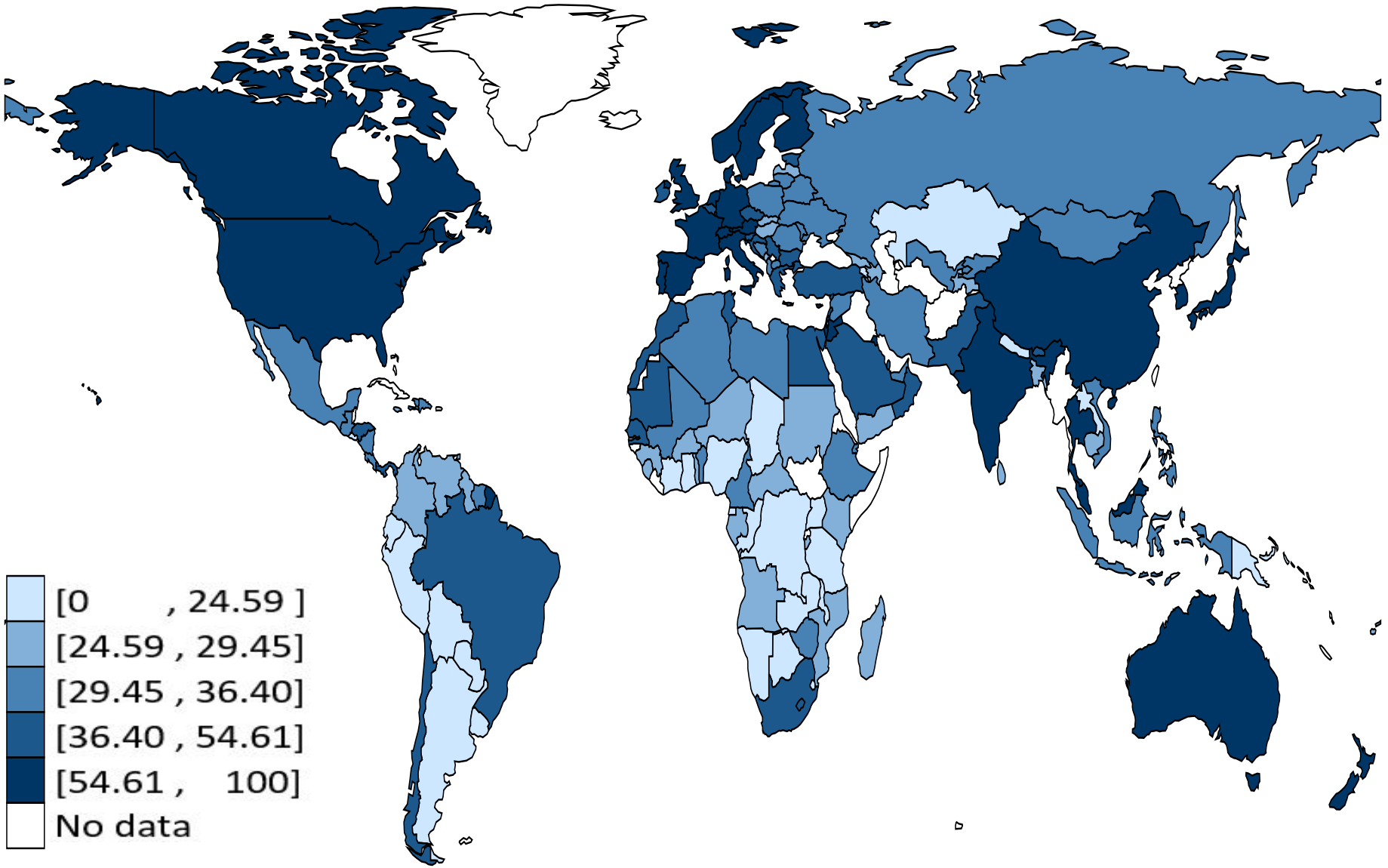

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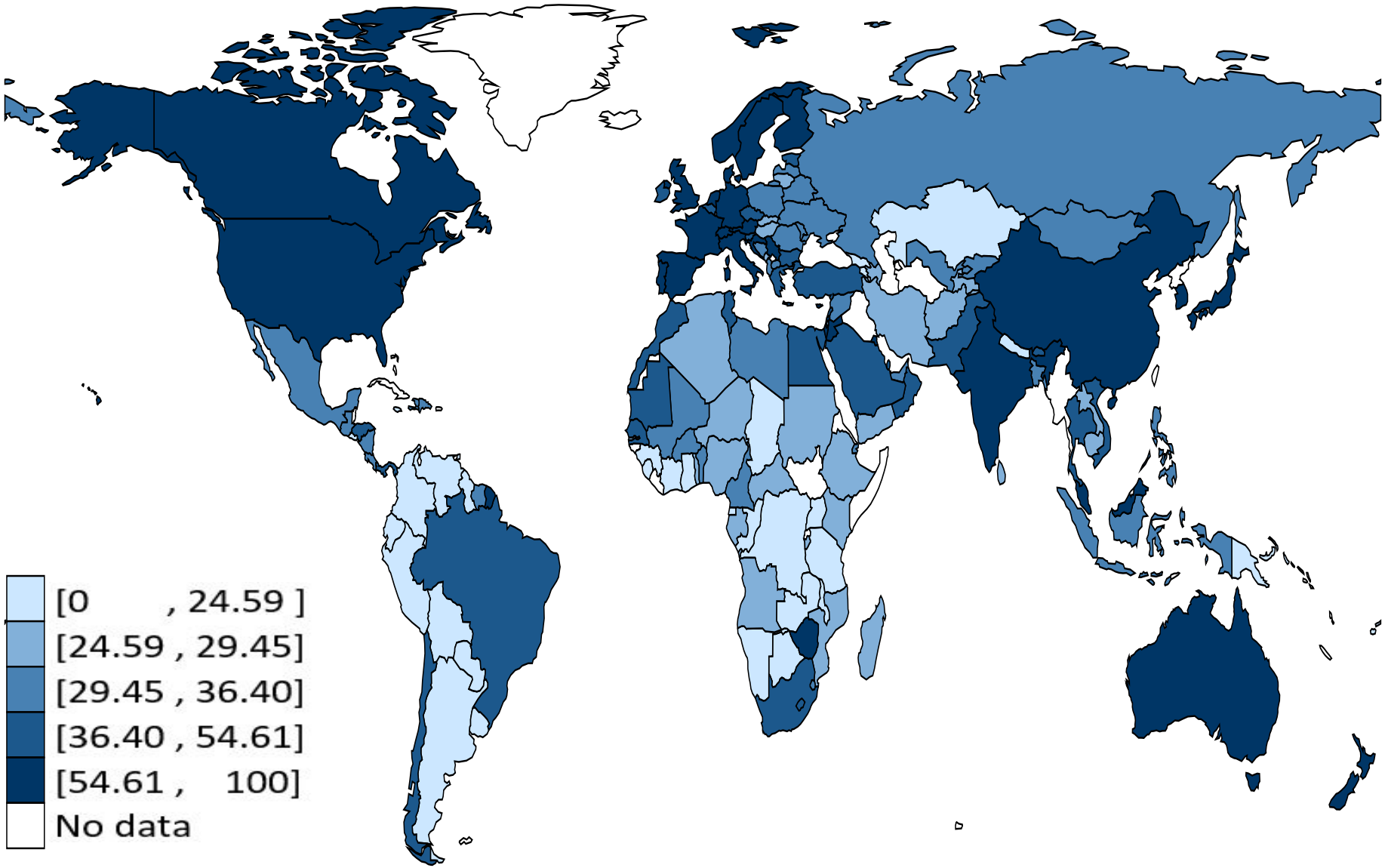

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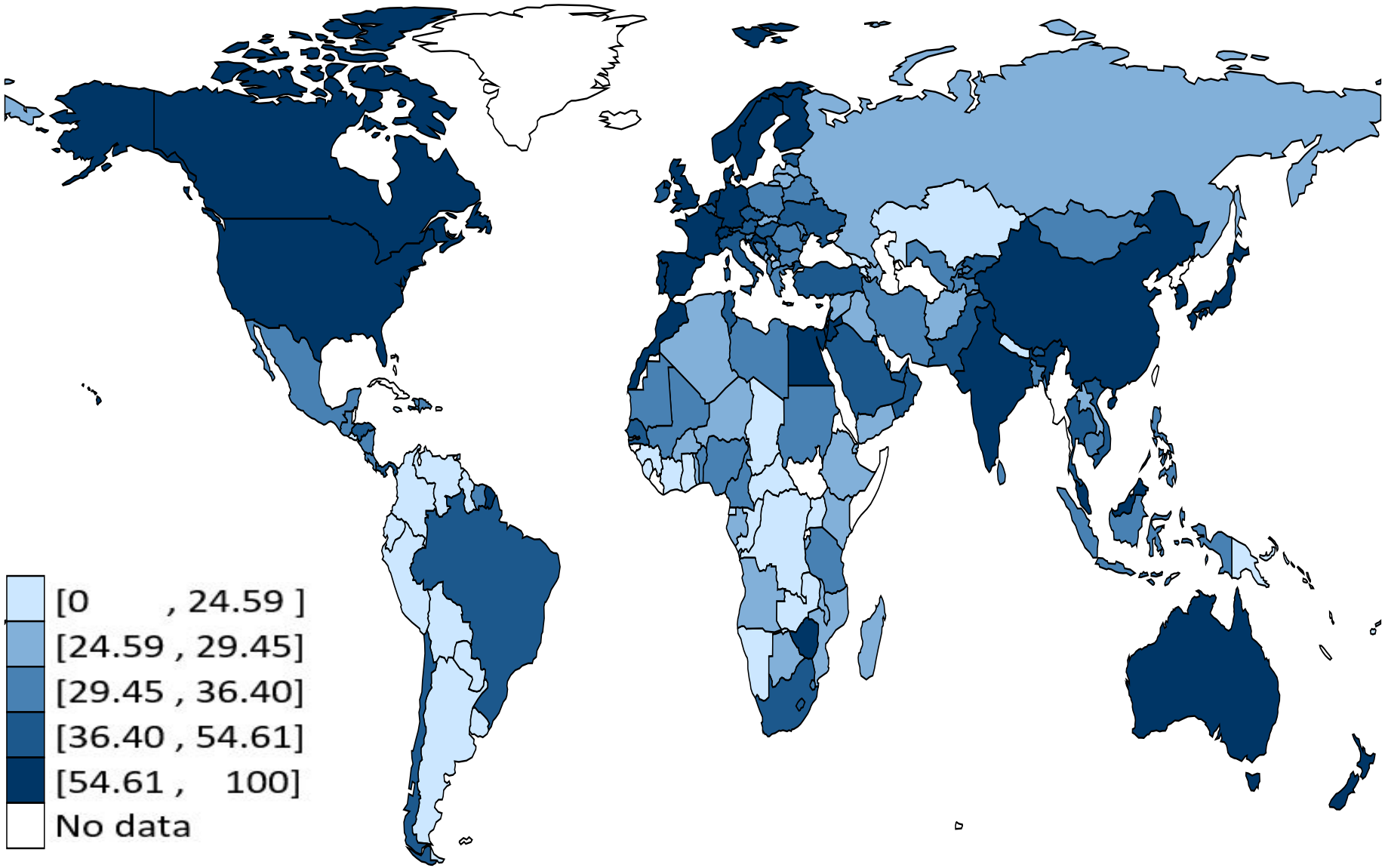

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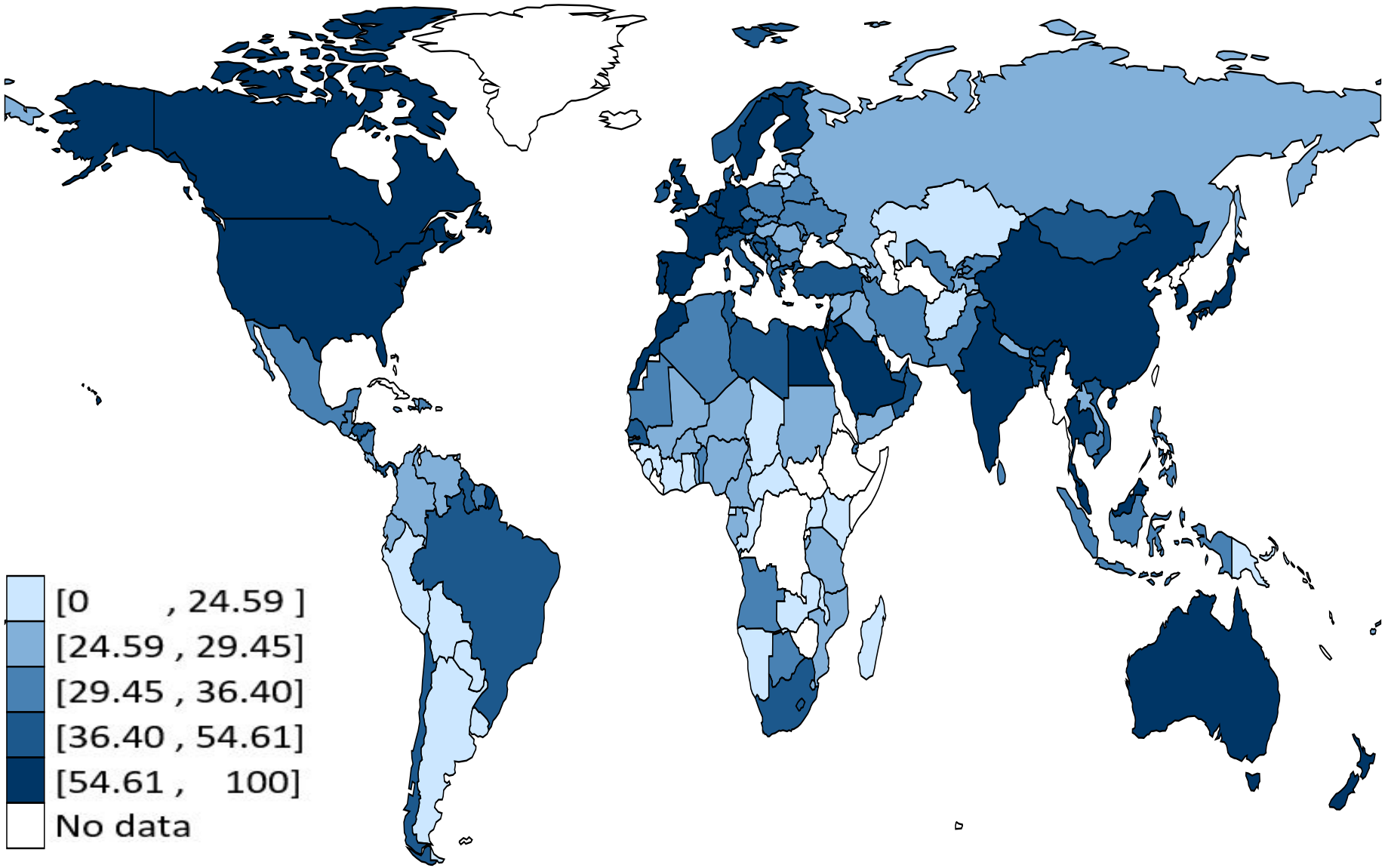

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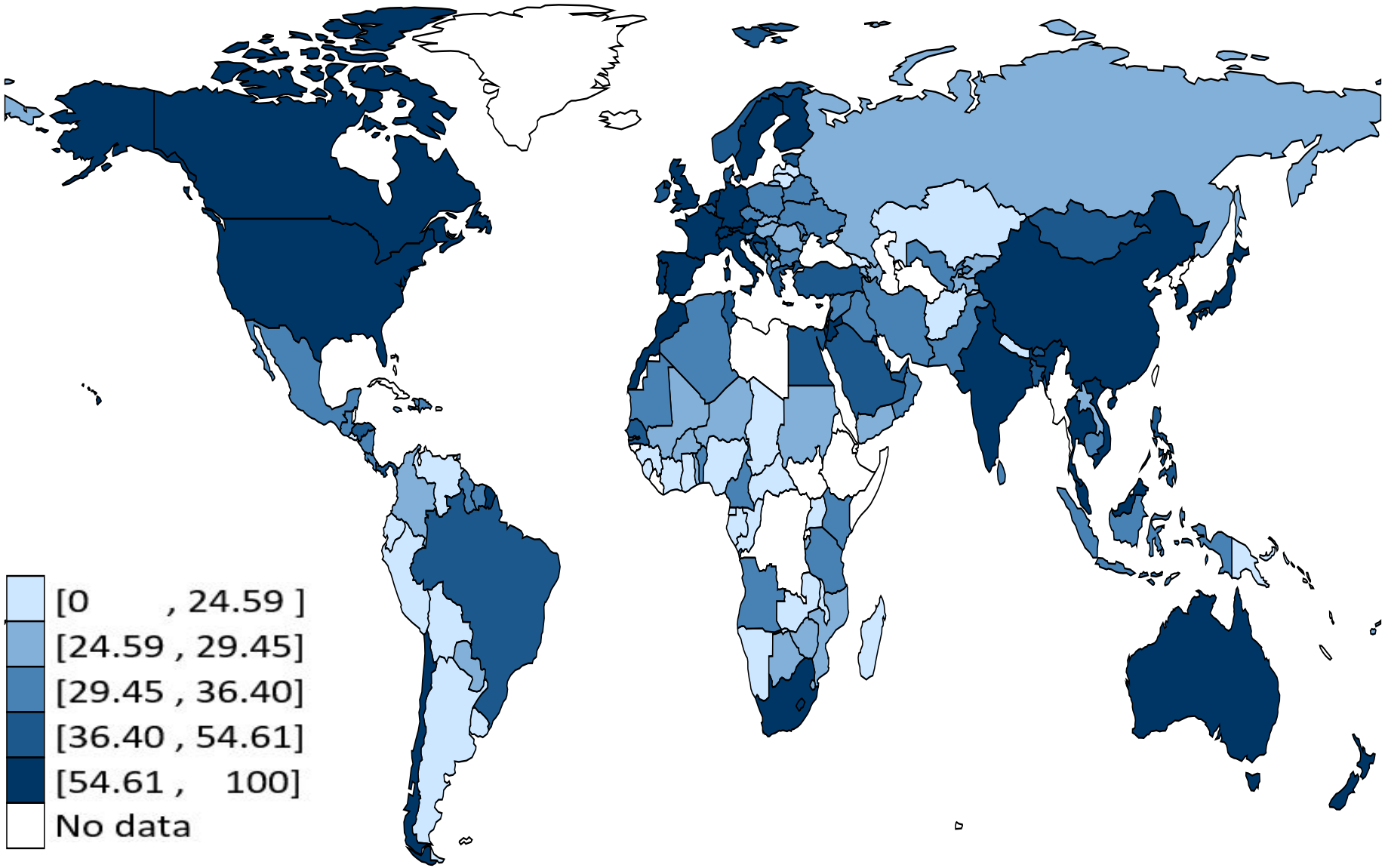

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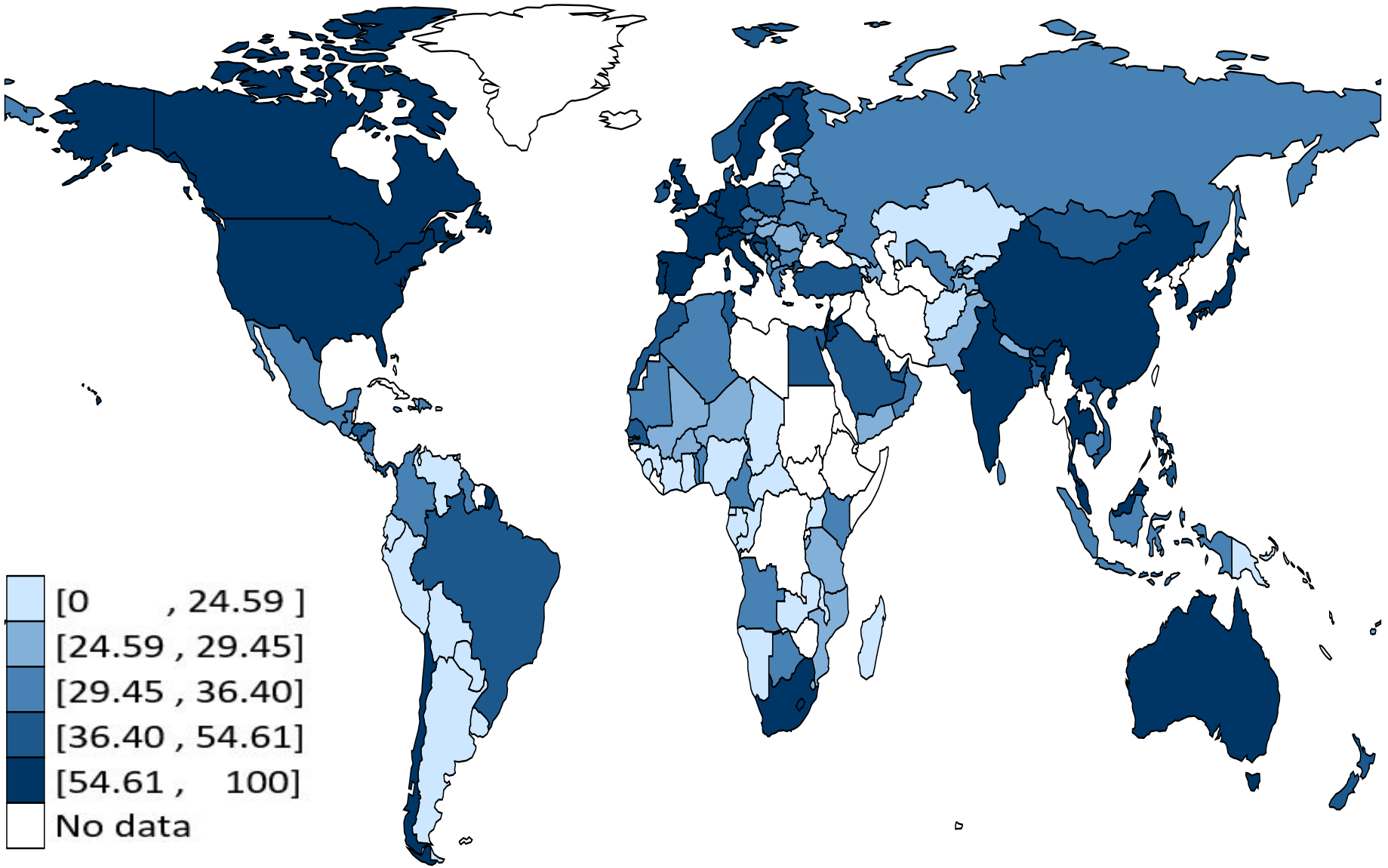

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