Cross-border Patenting, Globalization, and Development

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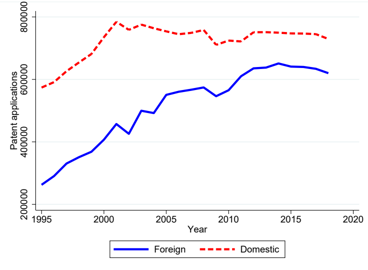
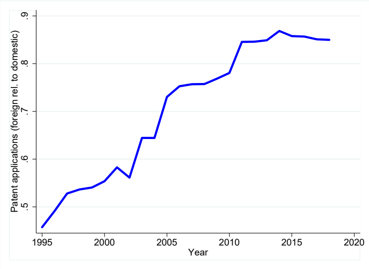
Evolution of Cross-border Patenting

- Between 1995 and 2018, foreign patent applications grew by 136% outpacing domestic applications (27%) – excluding those from China.





- **Most of the increase is driven by cross-border patenting from developed (North) to developing (South) economies (542%!!).**

This Paper

- **What are the drivers of the large increase in cross-border patenting, especially from North to South?**

- **What are the implications of cross-border patenting from North to South for global income inequality?**

Contributions and Outline

1. **New Data:** Build a novel, comprehensive panel dataset of cross-border patents and domestic patents across sectors (we also include citations).

2. **Theory:** Develop a model that yields a structural equation for cross-border patenting and guides our empirical analysis.

3. **Econometric Analysis:** Employ established methods to estimate the determinants of cross-border patenting.

4. **Quantitative Analysis:** Use our model, new data, and partial equilibrium estimates to conduct counterfactual analysis.

“International Patent and Citations across Sectors” INPACT-S Dataset

INPACT-S: Construction

1. **DATA SOURCE:** PATSTAT Global Autumn 2021
2. **KEY VARIABLES:** patent applications by origin country, application authority, IPC codes (4-digit), and filing year (1980-2018)
3. **FRACTIONAL COUNTING METHOD** Addresses multiple applicants/inventors from different countries and multiple IPC classifications per patent
4. **REGIONAL PATENT AUTHORITY APPLICATIONS** Dispersed to individual member states using a weighted-dispersion method
5. **IMPUTATION MISSING ORIGIN COUNTRIES**
6. **INDUSTRY DIMENSION:** Conversion of IPC codes to ISIC Rev 3 2-digit industries
7. **FAMILY PATENTS:** Consider all the patents of the family

INPACT-S: Dimensions and Key Features

- **PATENTS COVERAGE:** Over 49 million cross-border patent applications
- **TIME COVERAGE:** 39 years, over the period 1980–2018
- **COUNTRY COVERAGE:** 213 countries of origin and 91 patent authorities
- **SECTOR COVERAGE:** 31 sectors, classified according to ISIC Rev.3
- **DOMESTIC PATENTS:** Consistently constructed data for domestic patents
- **CITATIONS:** Detailed cross-country and cross-sector citation data
- **RELATED DATA:** More comprehensive than any other public dataset

INPACT-S is freely available for downloads. Details

Salient Data Patterns

- Europe and North America are the traditional hubs for innovation.
- Asia has been a very popular destination for patent applications.
- Asian countries (e.g., China, Japan, Korea) have emerged as leaders too.
- China is an outlier with an unprecedented growth of domestic patents.
- Patents concentrated in Chemicals, Computers, and Medical Equipment.
- **Cross-border patenting has grown faster than domestic applications.**
- **Most cross-border patents are from 'North' to 'South' (542% increase!).**

A Theory of Patent Flows

Assumptions

1. M countries, indexed by i and n; discrete time, indexed by t
2. Trade in intermediate goods, subject to iceberg transport costs
3. Innovators invest in R&D to create new ideas
4. Ideas diffuse, exogenously, to produce intermediate goods, creating returns to R&D, but imperfect IPR (i.e., imitation)
5. Innovators file patent applications to protect diffused ideas; patenting is costly
6. **Key Dynamics:**
   - Productivity driven by variety of goods
   - Trade affects diffusion and incentives for innovation
   - IPR protection influences patenting decisions and returns to innovation

Production

- Final producers buy T_{it} differentiated intermediate goods produced from each country i with a CES production function

$$Y_{nt} = \sum_{i=1}^{M} \left(\int_{j=1}^{T_{it}} X_{ni,t}^{\frac{\sigma-1}{\sigma}}(j)dj \right)^{\frac{\sigma}{\sigma-1}}$$

- Intermediate goods are produced by monopolistic competitors with labor

$$y_{nt}(j) = \Omega_{nt} l_{nt}(j)$$

- Intermediate goods are traded and subject to iceberg transport costs, $\mathbf{d_{in}}$
- Import share of country i from country n:

$$\pi_{in,t} = \Omega_{nt}^{\sigma-1} T_{nt} \frac{\left(\frac{\sigma}{\sigma-1} W_{nt} \mathbf{d_{in}}\right)^{1-\sigma}}{P_{it}^{1-\sigma}}$$

- T_{nt} evolves endogenously though innovation and diffusion

Innovation and International Diffusion

- Innovators in country n create new technologies at the rate:

$$Z_{nt} = \gamma_{nt} \left(\frac{H_{nt}}{Y_t^w} \right)^{\eta}$$

with γ_{nt} innovation efficiency and η diminishing returns to R&D

- An idea is a blueprint that can be used to produce a differentiated intermediate good (all ideas have the same quality)
- In every period t, a fraction $\varepsilon_{\mathbf{in,t}}$ of ideas created by country n diffuses to each other country i
- Number of intermediate goods produced in country i at time t:

$$T_{it} = \sum_{n=1}^{M} \varepsilon_{ni,t} Z_{nt}$$

Cross-border Patenting

- Innovators patent in each jurisdiction where their idea has diffused to reduce imitation, but patenting is a costly activity
- Innovators choose the fraction $\lambda_{in,t}$ to patent that maximizes

$$\underbrace{\lambda_{in,t} V_{in,t}^{\text{pat}} - C(\lambda_{in,t}) P_{it}}_{\text{Value of patenting}} + \underbrace{(1-\lambda_{in,t}) V_{in,t}^{\text{nopat}}}_{\text{Value of not patenting}}$$

- The value of a patented technology is given by:

$$V_{in,t}^{pat} = \varepsilon_{\mathbf{in,t}} \phi_{\mathbf{in,t}} \frac{\Pi_{it}}{T_{it}}$$

with $\phi_{\mathbf{in,t}}$ IP enforcement; $\Pi_{it} = \sum_{n=1}^{M} \pi_{ni,t}(d_{ni,t}) Y_{nt}$ intermediate producers' profits

- The FOC for the share of patented technologies is:

$$C'(\lambda_{in,t}) P_{it} = V_{in,t}^{pat} - V_{in,t}^{nopat}$$

Cross-border Patenting

- Assume $V_{in,t}^{nopat} = 0$ (all unpatented technologies are imitated) and cost of patenting:

$$C(\lambda_{in,t}) = \frac{1}{\xi}\tau_{in}(\lambda_{in,t})^{\xi}, \quad \xi > 1$$

- The share of patented technologies can be expressed as:

$$\lambda_{in,t} = {\tau_{in}}^{-1/(\xi-1)} \left(\frac{V_{in,t}^{pat}}{P_{it}}\right)^{1/(\xi-1)}$$

- The number of patented technologies is:

$$\text{Pat}_{in,t} = \lambda_{in,t}\varepsilon_{in,t}Z_{nt}$$

- Optimal innovation:

$$H_{nt} = \eta\frac{V_{nt}Z_{nt}}{P_{nt}}$$

with $V_{nt} = \sum_{i=1}^{M} V_{in,t}^{\text{pat}}$

Structural Equation Cross-border Patenting

Cross-border patenting from country n to country i at time t is given by:

$$\text{Pat}_{in,t} = \underbrace{\frac{H_{nt}P_{nt}}{\eta V_{nt}}}_{\text{Source innovation}} \underbrace{\left(\frac{\Pi_{it}}{P_{it}T_{it}}\right)^{1/(\xi-1)}}_{\text{Destination Attractiveness}} \underbrace{(\tau_{in})^{-1/(\xi-1)}}_{\text{Bilateral patenting frictions}} \underbrace{\boldsymbol{\varepsilon_{in,t}}^{\frac{\xi}{\xi-1}}}_{\text{Diffusion}} \underbrace{(\boldsymbol{\phi_{in,t}})^{1/(\xi-1)}}_{\text{Policy}}.$$

Structural Estimating Equation

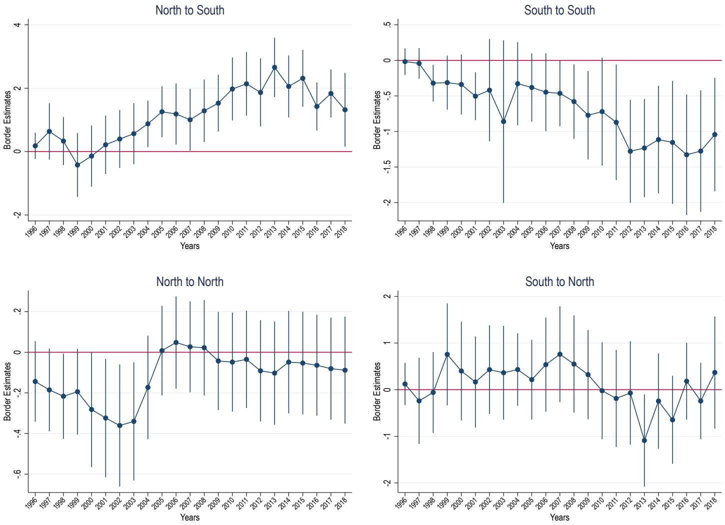
$$\text{Pat}_{in,t} = \exp[\pi_{n,t} + \chi_{i,t} + \overrightarrow{\gamma_{in}} + \sum_t \gamma_t \mathbf{BRDR_{in,t}} + \mathbf{POLICY_{in,t}}\beta] \times \epsilon_{in,t} \quad \forall i, n$$

Structural Equation for Cross-border Patents

$$Pat_{in,t} = \exp[\pi_{n,t} + \chi_{i,t} + \overrightarrow{\gamma_{in}} + \sum_t \gamma_t BRDR_{in,t} + POLICY_{in,t}\beta] \times \epsilon_{in,t} \quad \forall i, n$$

- **Estimate equation with PPML.**
- **Use panel data.**
- **Use domestic patents.**
- **Use source-time and destination-time fixed effects.**
- **Use directional pair fixed effects.**
- **Account for globalization (diffusion, policy) trends.**
- **Obtain estimates of the effects of policies, e.g., RTAs, TRIPS, PCT.**
- **Cluster standard errors by pair and/or three-way.**

Diffusion & Patent Flows



Globalization has increased patent flows from developed to developing countries by 300% between 1995-2018

Policy & Patent Flows

	RTA	TECH	TRIPS	PCT
RTA_S_N	0.175			
	(0.064)**			
RTA_N_N	0.239			
	(0.044)**			
RTA_TECH_S_N		0.196	0.201	0.196
		(0.053)**	(0.052)**	(0.053)**
RTA_TECH_N_N		0.221	0.209	0.208
		(0.043)**	(0.041)**	(0.042)**
RTA_NO_TECH_N_N		1.178	1.159	1.157
		(0.159)**	(0.155)**	(0.155)**
TRIPS_S_S			0.502	0.514
			(0.228)*	(0.207)*
TRIPS_N_N			0.209	0.210
			(0.126)+	(0.126)+
PCT_S_S				1.271
				(0.319)**
PCT_N_N				0.177
				(0.083)*
N	63846	63846	63846	63846

Diffusion, Policy & Patent Flows

1. RTAs boost cross-border patent flows, especially South to North.
2. Effects are heterogeneous across:
   2.1 Agreement types (those with and without technology provisions)
   2.2 Country groupings
3. Other policies like TRIPS and PCT show varied impacts across different country groups.
4. **Policy had non significant effect on patents from North to South**
5. Diffusion explains about 55% of the increase in cross-border patenting from North to South

Quantitative Analysis

Connecting Back to Theory (1/2)

We have found the increase in N-S patent flows is driven by diffusion ($\uparrow \varepsilon_{SN,t}$), not policy ($\phi_{SN,t}$):

1. **$\uparrow \varepsilon_{SN,t}$ and $\uparrow \phi_{SN,t}$ increase patenting; different implications for inequality**
2. **Technology Transfer:** $T_{SN,t} = \varepsilon_{SN,t} Z_{Nt}$
   - (+) Diffusion: Direct benefit to South through increased tech transfer; indirect effect through Z_{Nt}
   - ($\approx$) Policy: Limited direct effect on tech transfer; indirect effect through Z_{Nt}
3. **Patent Share:** $\lambda_{SN,t} = {\tau_{SN}}^{-1/(\xi-1)} \left(\frac{\varepsilon_{SN,t} \phi_{SN,t} \Pi_{St}}{T_{St} P_{Nt}} \right)^{1/(\xi-1)}$
   - (+) Diffusion: More tech for South, some increase in royalties
   - (-) Policy: Higher royalties without necessarily more tech

Connecting Back to Theory (2/2)

Implications for Inequality:

- Diffusion: South gains more technology, both patented and unpatented

$$\varepsilon_{SN,t}\lambda_{SN,t}Z_{Nt} + \varepsilon_{SN,t}(1 - \lambda_{SN,t})Z_{Nt}$$

- Policy: Increases patented share without expanding tech base
- Diffusion leads to productivity gains in South, potentially reducing inequality

$\Rightarrow$ Policy may exacerbate inequality by increasing costs without transfer gains

Key Insight: While both diffusion and policy increase patenting, diffusion-driven flows may reduce global inequality.

Counterfactual Analysis

- Our empirical analysis shows that globalization has been particularly important for cross-border patenting from North to South.
- We use our model, data, and partial equilibrium estimates to ask:

1. **What would have been the trajectory of cross-border patenting from North to South between 1995 and 2018 if globalization trends had remained at their 1995 levels?**
2. **What are the implications of cross-border patenting from North to South for global income inequality?**

Calibration Strategy

Parameters from Previous Studies and Data

Armington elasticity (σ): 5 (trade elasticity of 4)

Elasticity of innovation (η): 0.5

Population: Taken from CEPII database

Iceberg transport costs and productivity parameters: Calibrated using data on trade flows, geography measures, GDP, and population from CEPII; Gravity methods using PPML

Elasticity of patenting costs (ξ): 2 (increasing marginal costs)

Diffusion 1995 ($\varepsilon_{in,1995}$): Cross-section structural equation of cross-border patents

Foreign IP enforcement (ϕ_{in}): 0.25 (innovators receive 25% of profits from foreign adopters, except for South paying one-tenth to North)

Domestic IP enforcement (ϕ_{ii}): 0.5 (domestic innovators and adopters split surplus equally)

Cross-section with 'standard gravity' and directional border effects

$$Pat_{in} = \exp[\pi_n + \chi_i + \gamma BRDR_{in} + GRAV_{in}\alpha] \times \epsilon_{in} \quad \forall i, n$$

	1995	1995	2006	2018
LN_DIST				
CNTG				
LANG				
CLNY				
BRDR				
BRDR_N_N				
BRDR_N_S				
BRDR_S_S				
BRDR_S_N				
N				

Cross-section with 'standard gravity' and directional border effects

$$Pat_{in} = \exp[\pi_n + \chi_i + \gamma BRDR_{in} + GRAV_{in}\alpha] \times \epsilon_{in} \quad \forall i, n$$

	1995	1995	2006	2018
LN_DIST	-0.350			
	(0.072)**			
CNTG	-0.186			
	(0.223)			
LANG	1.403			
	(0.202)**			
CLNY	0.025			
	(0.270)			
BRDR	-2.404			
	(0.366)**			
BRDR_N_N				
BRDR_N_S				
BRDR_S_S				
BRDR_S_N				
N	2326			

Cross-section with 'standard gravity' and directional border effects

$$Pat_{in} = \exp[\pi_n + \chi_i + \gamma BRDR_{in} + GRAV_{in}\alpha] \times \epsilon_{in} \quad \forall i, n$$

	1995	1995	2006	2018
LN_DIST	-0.350	-0.418		
	(0.072)**	(0.075)**		
CNTG	-0.186	-0.370		
	(0.223)	(0.231)		
LANG	1.403	1.313		
	(0.202)**	(0.187)**		
CLNY	0.025	-0.120		
	(0.270)	(0.282)		
BRDR	-2.404			
	(0.366)**			
BRDR_N_N		-1.939		
		(0.391)**		
BRDR_N_S		-3.050		
		(0.497)**		
BRDR_S_S		-4.440		
		(0.553)**		
BRDR_S_N		-5.740		
		(0.667)**		
N	2326	2326		

Cross-section with ‘standard gravity’ and directional border effects

$$Pat_{in} = \exp[\pi_n + \chi_i + \gamma BRDR_{in} + GRAV_{in}\alpha] \times \epsilon_{in} \quad \forall i, n$$

	1995	1995	2006	2018
LN_DIST	-0.350	-0.418	-0.314	
	(0.072)**	(0.075)**	(0.071)**	
CNTG	-0.186	-0.370	-0.458	
	(0.223)	(0.231)	(0.268)+	
LANG	1.403	1.313	1.315	
	(0.202)**	(0.187)**	(0.198)**	
CLNY	0.025	-0.120	-0.430	
	(0.270)	(0.282)	(0.246)+	
BRDR	-2.404			
	(0.366)**			
BRDR_N_N		-1.939	-1.736	
		(0.391)**	(0.356)**	
BRDR_N_S		-3.050	-2.851	
		(0.497)**	(0.661)**	
BRDR_S_S		-4.440	-4.724	
		(0.553)**	(0.570)**	
BRDR_S_N		-5.740	-3.741	
		(0.667)**	(0.790)**	
N	2326	2326	2782	

Cross-section with 'standard gravity' and directional border effects

$$Pat_{in} = \exp[\pi_n + \chi_i + \gamma BRDR_{in} + GRAV_{in}\alpha] \times \epsilon_{in} \quad \forall i, n$$

	1995	1995	2006	2018
LN_DIST	-0.350	-0.418	-0.314	-0.218
	(0.072)**	(0.075)**	(0.071)**	(0.071)**
CNTG	-0.186	-0.370	-0.458	-0.682
	(0.223)	(0.231)	(0.268)+	(0.333)*
LANG	1.403	1.313	1.315	1.363
	(0.202)**	(0.187)**	(0.198)**	(0.161)**
CLNY	0.025	-0.120	-0.430	-0.359
	(0.270)	(0.282)	(0.246)+	(0.234)
BRDR	-2.404			
	(0.366)**			
BRDR_N_N		-1.939	-1.736	-2.023
		(0.391)**	(0.356)**	(0.360)**
BRDR_N_S		-3.050	-2.851	-2.893
		(0.497)**	(0.661)**	(0.843)**
BRDR_S_S		-4.440	-4.724	-4.401
		(0.553)**	(0.570)**	(0.334)**
BRDR_S_N		-5.740	-3.741	-3.253
		(0.667)**	(0.790)**	(0.814)**
N	2326	2326	2782	2488

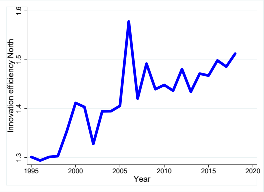
Calibrated Parameters

Parameter	Value	Description
σ	5	Armington elasticity
d_{NS}	6.60	Iceberg trade costs from S to N
d_{SN}	6.13	Iceberg trade costs from N to S
η	0.50	Elasticity of innovation
L_N	0.71	Population N
L_S	1	Population S
ξ	2	Elasticity in the cost of patenting
ϕ_{SN}	0.25	Santacreu (2023)
ϕ_{NS}	0.025	Santacreu (2023)
ϕ_{NN}	0.5	Santacreu (2023)
ϕ_{SS}	0.5	Santacreu (2023)
ε_{NS}	0.48	Gravity 1995
ε_{SN}	0.52	Gravity 1995
$\varepsilon_{SN,t}$		Calibrated to match globalization trends
γ_{nt}		Calibrated to match R&D data

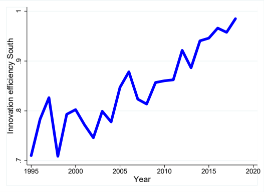
Calibration Strategy
Remaining Parameters

- Innovation efficiency (γ_{nt}) and diffusion forces ($\varepsilon_{SN,t}$): Calibrated to match data on R&D intensity and border effect from main specification

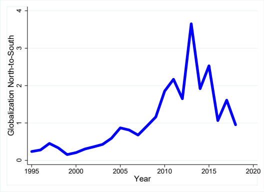
γ_{Nt}



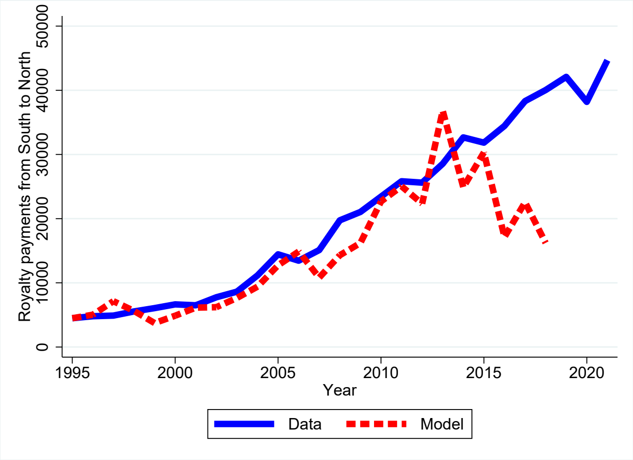
γ_{St}



$\varepsilon_{SN,t}$

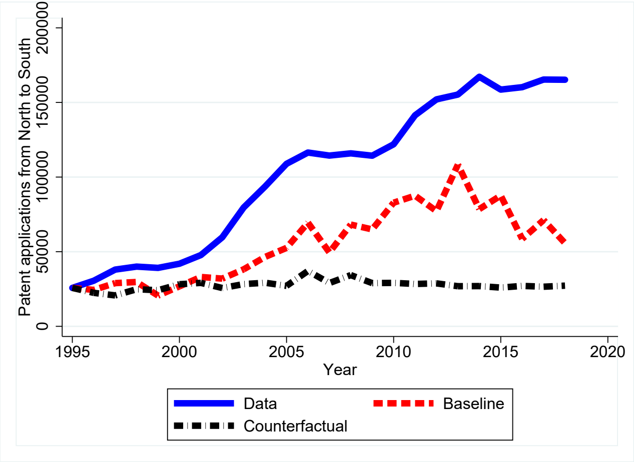


External Validation: Royalty Payments



Cross-border Patenting without Globalization

Counterfactual: Set the trajectory for $\varepsilon_{SN,t}$ to its 1995 value $\forall t$



Cross-border Patenting and Inequality

	1995-2018	2000-2018
Cross-border patenting	38%	46%
Income inequality	-12.6%	-15.6%

Cross-border patents from North to South would have been 38% lower.

Globalization has benefited both ‘North’ and ‘South’, but it has made poor countries relatively richer.

Income inequality 12.6% lower due to globalization forces!

Concluding Remarks

- Both diffusion and policy increase cross-border patenting
- However, their implications for inequality differ:
  - **Diffusion:** Increases tech transfer, reduces inequality
  - **Policy:** May increase costs without commensurate tech gains
- Key insight: Diffusion-driven flows more effectively promote technology transfer and reduce global inequality
- Quantitative result: Globalization reduced income inequality by 12.6% (1995-2018)

Construction of INPACT-S Dataset

- Data source: PATSTAT Global Autumn 2021
- Key variables: patent applications by origin country, application authority, IPC codes (4-digit), and filing year (1980-2018)
- Concordance tables used to convert IPC codes to ISIC Rev 3 2-digit industry codes
- Final dataset dimensions: 91 patent authorities, 213 origin countries, 39 years, and 31 ISIC Rev 3 2-digit codes

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Data Adjustments and Imputation

1. Fractional counting method:
   - Addresses multiple applicants/inventors from different countries and multiple IPC classifications per patent
   - Avoids double-counting by assigning fractional values based on the number of applicants/inventors and IPC codes
2. Regional patent authority applications:
   - Dispersed to individual member states using a weighted-dispersion method
   - Weights based on the share of direct patent applications from each origin country to each member state

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Data Adjustments and Imputation

1. Imputation of missing origin countries:
   - Step 1: Use the method by De Rassenfosse et al. to impute missing values using familial linkages between worldwide applications
   - Step 2: Disperse remaining "origin missing" applications using aggregate bilateral data from WIPO as weights
2. Conversion of IPC codes to ISIC Rev 3 2-digit industries:
   - Use crosswalk from Lybbert and Zolas (2012)
   - Multiply patent numbers by probability weights and sum by industries

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Key Assumptions and Limitations

1. All patents from the same family are considered, not just the first patent
2. Weighted-dispersion method assumes that not all member states of a regional authority attract patent applications equally
3. Imputation of missing origin countries assumes that probabilities are constant across all technology classes for each origin/authority/year relationship
4. Conversion to ISIC industries relies on the accuracy of the crosswalk and probability weights

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