Occupational Variety and Economic Development

Anton Heil
LSE

Gabriel Leite-Mariante
CUNEF

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Industrialisation with Occupations

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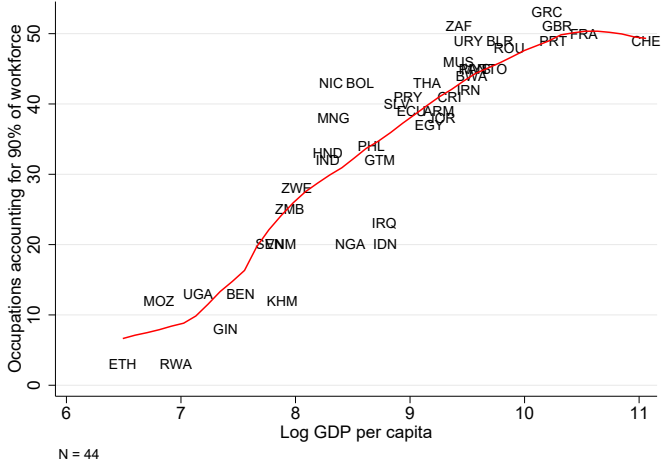
Industrialisation with Occupations



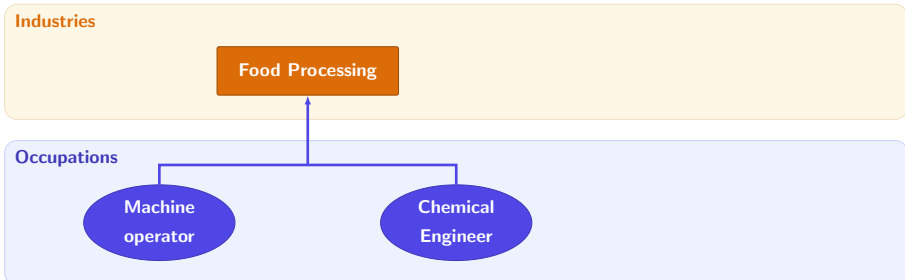
Source: IPUMS international, harmonized census data, ISCO 116 minor groups (3-digits)

by ISCO | historical | to 80% | to 95% | Fractionalisation | Theil

Industrialisation with Occupations

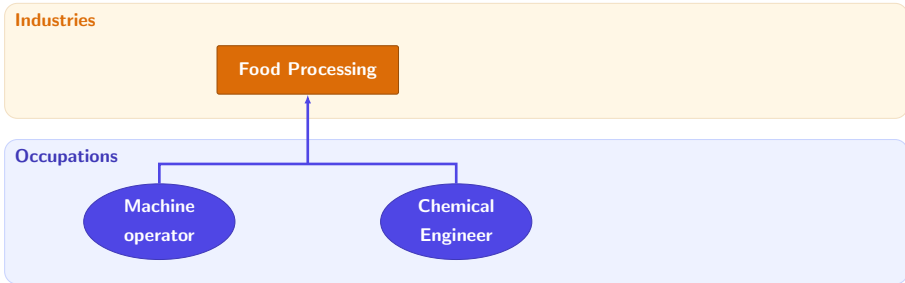
- Development involves industrialisation (producing new goods and services) figure
- Classical theories of development highlight linkages between industries (Rosenstein-Rodan, 1943; Hirschman, 1958)
- **New channel:** Industries are linked through their specific skill requirements
  - Occupations capture specialised skills
- **Question:** Does occupational structure affect industrialisation, and if yes, how?
- **This paper:** Occupation-based linkages between industries

Example: specific skill requirements



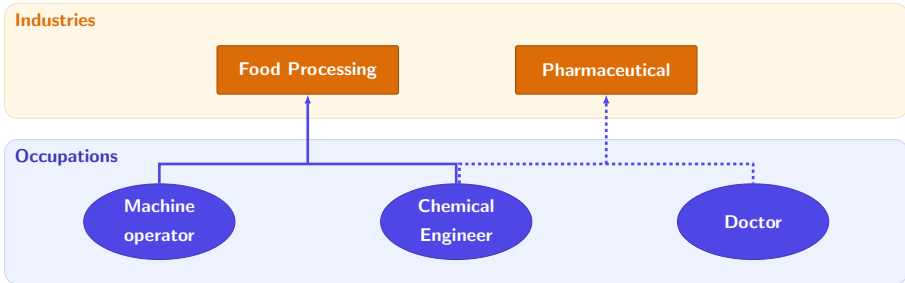
- Lack of specifically trained labour can hold up industrialisation

Example: specific skill requirements



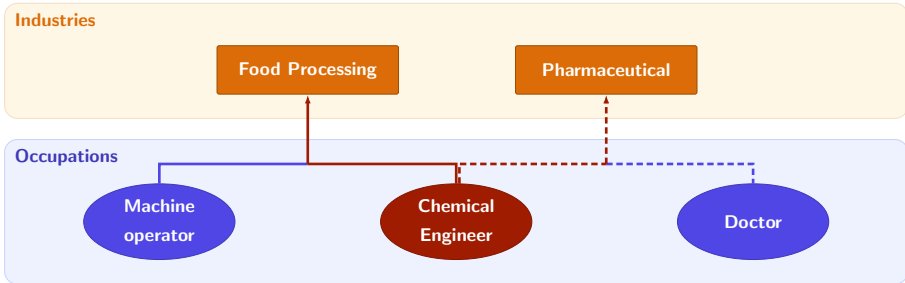
- Lack of specifically trained labour can hold up industrialisation
- Industry entry constitutes a **coordination problem**
  - industries need specifically trained workers
  - workers only train if they expect to be hired

Example: industry entry with occupation overlap



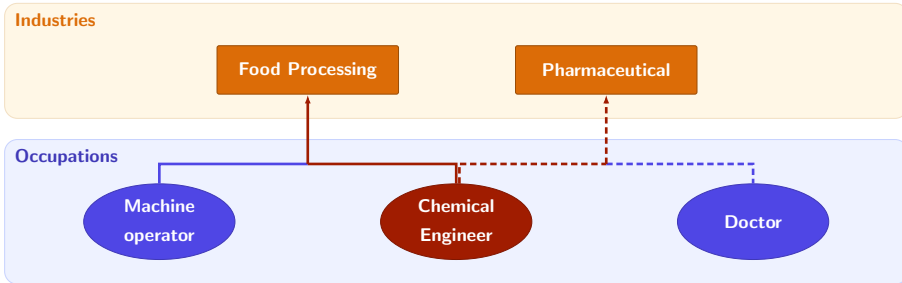
- Food Processing and Pharmaceutical are linked through their common use of chemical engineers

Example: occupation-based linkage



- Positive externality:
  - Entry of Food Processing incentivises workers to train as chemical engineers
  - Thicker market for chemists facilitates entry of pharmaceutical

Example: occupation-based linkage



- Positive externality:
  - Entry of Food Processing incentivises workers to train as chemical engineers
  - Thicker market for chemists facilitates entry of pharmaceutical
- Negative externality: industries compete for workers

This paper: structure and results

Formalise and test the idea of occupation-based linkages using micro-data from Brazil

1. **Stylised Facts**
   - New occupations and industries emerge jointly
   - Bi-directional network of industries and occupations
2. **Model of occupation-based linkages**
3. **Testing occupation-based linkages**
   - Shift-share IV: occupation-based linkage to existing industry predicts entry
   - Robust to and of similar magnitude as input-output linkages
   - Aggregate linkages predict regional growth conditional on current GRP

Literature

We build on:

- Human capital externalities and agglomeration (e.g. Marshall (1890), Jacobs (1969), Diamond (1982), Helsley and Strange (1990), Krugman (1991), Acemoglu (1997), Lazear (2009), Ellison et al. (2010), Duranton and Puga (2004), and Papageorgiou (2022))

Contribution: occupation-based linkages

- Labour-centred perspective on industrialisation and industrial policy (e.g. Murphy et al. (1989), Rodrik (1996), Jones (2011), Liu (2019), and Lane (2025))
- Micro-foundations of economic complexity (e.g. Hausmann et al. (2007), Hidalgo et al. (2007), Hidalgo and Hausmann (2009), and Neffke and Henning (2013))
- Specialisation of labour in occupations (e.g. Rodriguez-Clare (1996) and Hsieh et al. (2019))

Structure

1. Stylised Facts
2. Theory: Industrialisation with Occupations
3. Testing for occupation-based Linkages

Data

Cross-country: harmonized census micro-data data (IPUMS)

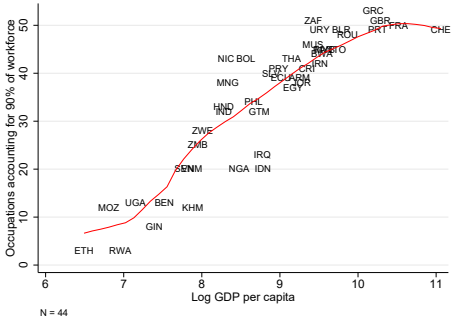
Brazil: Relação Anual de Informações Sociais (RAIS)

- Universe of *formal* employment contracts, 2003-2021
- 6-digits occupation codes (CBO, ca 2700) examples
- 5-digit industry codes (CNAE, ca 600)
- worker demographics, education, wages, hours worked

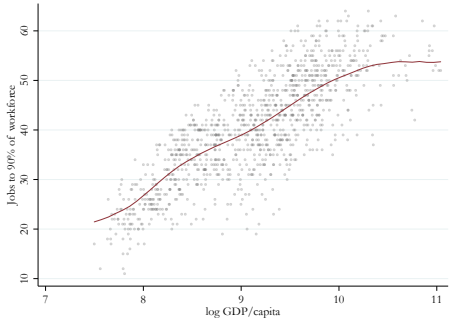
Additional data: municipal GDP and exports (IBGE), international trade (CEPII)

Why Brazil?

(a) The World



(b) Brazil

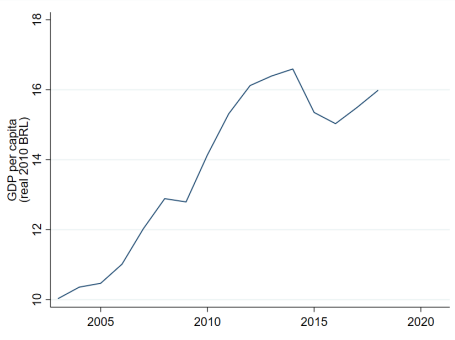


Source: IPUMS (left); 2010 Population Census, IBGE (right)

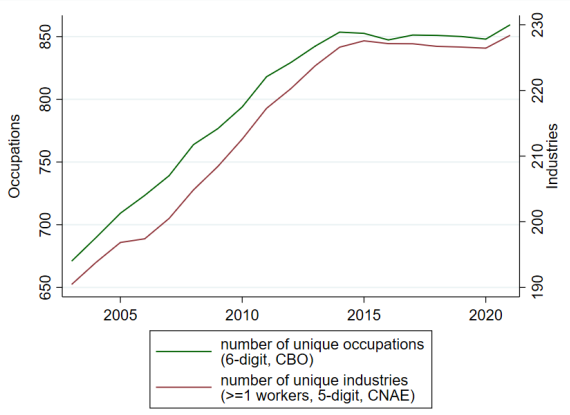
RAIS By region

1) Occupations and Industries growth with regional GDP

(a) GDP per capita, micro-region average

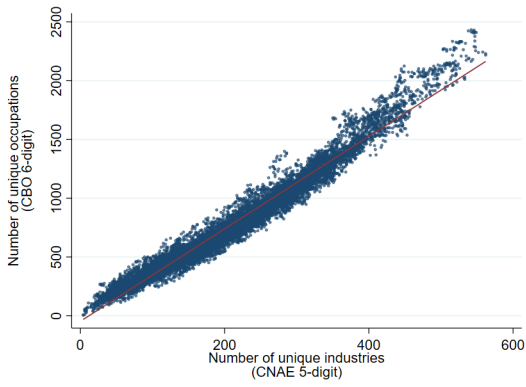


(b) Occupations and Industries



Table

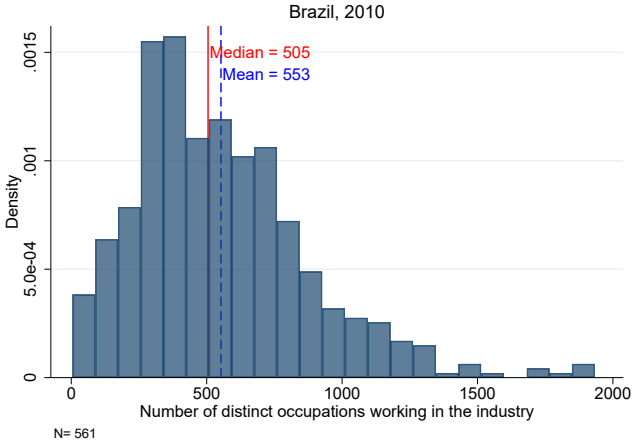
2) Higher occupational variety only possible with more industries



- Occupational variety increases (mostly) due to new products
- New products require new specialised occupations

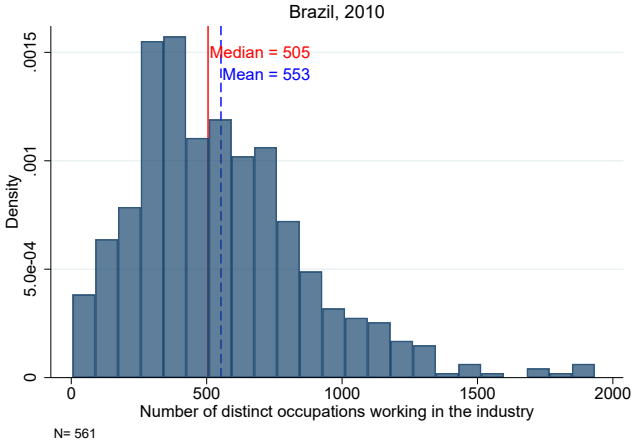
Table Within-industry Table GDP

3) Industries hire workers from different occupations



heatmap

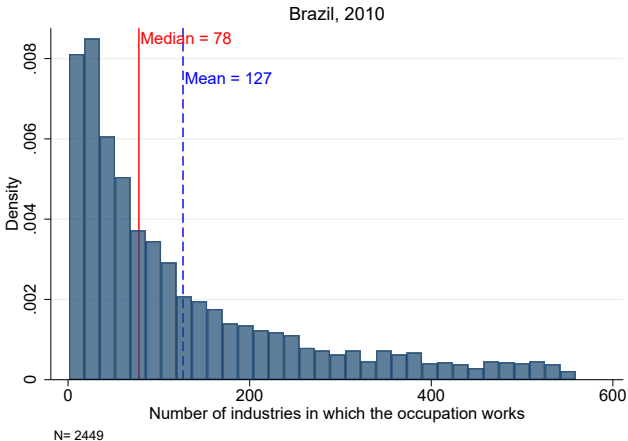
3) Industries hire workers from different occupations



Industries with few occs:	
Cocoa cultivation	196
Fabrication of agricultural tractors	286
Industries median occs:	
Wholesale trade of meat products	505
Cotton weaving	524
Industries with many occs:	
Telecommunications	716
Manufacture of organic chemicals	885

heatmap

4) Workers of the same occupation work in different industries



heatmap | occ-size scatter

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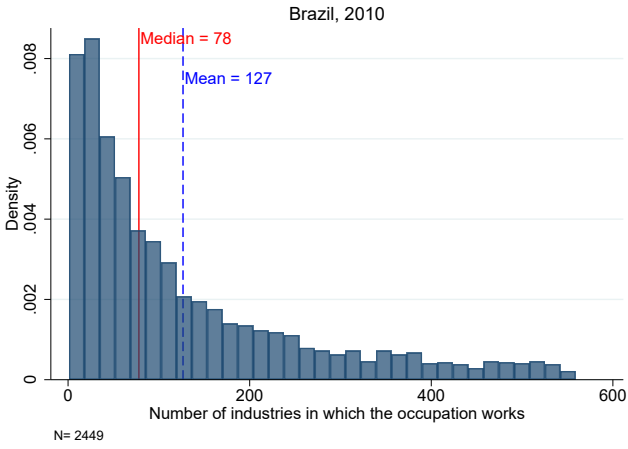

Occs in few industries:	
particle physicist	2
artisan knitter	3
water polo referee	2
Occs with median industries:	
carpenter	79
sound technician	80
insurance broker	91
Occs with many industries:	
chemical engineer	320
databank administrator	321
legal services assistant	367
Occs in almost all industries:	
production and operations manager	535
accountant	545
passenger car driver	552

heatmap occ-size scatter

Structure

1. Stylised Facts
2. Theory: Industrialisation with Occupations
3. Testing for occupation-based Linkages

Set-up

- Set of possible occupations $\mathcal{N}$ and industries $\mathcal{I}$ (indexed by n and i)
- Workers chose one occupation with occ-specific talent (Hsieh et al., 2019)
- Industries: unit mass of firms with fixed occupation requirements $S_i \subseteq \mathcal{N}$
- Matching frictions with strong thick market externalities (Diamond, 1982)

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- Matching frictions with strong thick market externalities (Diamond, 1982)
- Discrete time, t, each worker lives for 1 period
- Stock variables:
  - mass of active firms in each industry, $\lambda_{i,t}$
  - active industries $I_t^a \subseteq \mathcal{I}$; "dormant" industries $I_t^d = \mathcal{I} \setminus I_a$ (and occupations N_t^a, N_t^d)

Workers: Choice over active occupations

Worker ω's utility if choosing occupation n:

$$U_n(\omega) = \frac{\pi_n w_n a_n(\omega)}{\chi_n} \quad \text{, with} \quad a_n(\omega) \overset{\text{iid}}{\sim} \text{Fréchet}(1, \theta), \quad \theta > 1$$

- π_n probability of getting hired in occupation n
- w_n wage of n
- χ_n cost to enter n (e.g. training)

Effective labour supply:

$$\tilde{L}_n^S(\pi_n, w_n, N_t^a) = \bar{a}_n L_n^S = \left(\frac{\pi_n w_n}{\chi_n}\right)^{\theta-1} G(N_t^a, \theta)$$

Details occupational choice | aggregate productivity

Firms: Entry conditional on wages in all required occupations

- Firms in industry i require all occupations in $S_i \subseteq \mathcal{N}$ with intensities $b_{n,i}$

$$y_i(k) = min_{n \in S_i}\{b_{n,i}\tilde{L}_n\}$$

- Entry requires a firm-specific fixed cost $F(k) \overset{\text{iid}}{\sim} H_F$
- Mass of new entrants:

$$\lambda_t^e = \underbrace{(1-\lambda_t^a)}_{\text{dormant firms}} \times \underbrace{H_F(1-c_i(w))}_{\text{entry probability}}$$

- Unit variable cost: $c_i = \sum_{n \in S_i} \frac{w_n}{b_{n,i}\bar{a}_n}$
- Mass of active firms in industry i: $\lambda_{i,t} = \lambda_{i,t}^{\text{active}} + \lambda_{i,t}^{\text{new entrants}}$

Matching frictions with thick market effects

Hiring probability = share of active firms out of all firms that can hire n:

$$\pi_n(\lambda_t) = \frac{\lambda^a_{n,t} + \lambda^e_{n,t}}{\Lambda_n}$$

with

- $\Lambda_n = \sum_{i \in \mathcal{I}} \mathbb{I}[n \in S(k)]$ is the mass of all firms that hire n
- $\lambda^a_{n,t} = \sum_{i:n \in S_i} \lambda^a_{i,t}$ already active firms at the beginning of t hiring n
- $\lambda^e_{n,t} = \sum_{i:n \in S_i} \lambda^e_{i,t}$ new entrants in t hiring n

Labour market: two effects

- Matching frictions $\implies$ to fill one vacancy, need $\frac{1}{\pi_n}$ workers.
- Market clearing condition: $\tilde{L}_n^D(\lambda(w)) = \pi_n \tilde{L}_n^S(w_n, \pi_n)$
- Equilibrium wage:

$$w_n(\lambda_t) = \frac{\tilde{L}_n^D(\lambda_t)^{\frac{1}{\theta-1}}}{\pi_n(\lambda_t)^{\frac{\theta}{\theta-1}}} \chi_n G(N_t^a, \theta)^{\frac{1}{1-\theta}}$$

- labour demand channel: raises wage
- thick market externality: lowers wage
- thick market externality dominates ($\theta > 1$)

details: labor market clearing | details: within period entry equilibrium

Coordination problem of industry entry

Consider 1 dormant industry that hires 1 occupation:

- Entry probability for any one firm is $H_F(1 - c_i)$ with

$$1 - c_i(\lambda_{i,t}) = 1 - \frac{\chi_n}{\lambda_{i,t}} b_{ni}^{\frac{\theta+1}{1-\theta}} \kappa(N_t^a, \Lambda_n, \theta)$$

- Entry more likely if
  - larger mass of already active firms or expected entrants ($\lambda_{i,t}$)
  - n has high productivity in i (b_{ni})
  - lower training cost χ_n
- Coordination problem: $\boldsymbol{\lambda}_t^e = H\left[1 - c_i(w(\boldsymbol{\lambda}_t^e))\right]$
- If fixed cost doesn't allow enough (other) firms to enter $\Rightarrow$ no entry

details: stagnation and entry

Result: Occupation based linkage between industries

Consider 2 industries that hire the same occupation:

- Industry 1: active ($\lambda_1^a > 0$)
- Industry 2: dormant ($\lambda_2^a = 0$)
- Firm in 2 considering entry has operating profits:

$$1 - c_i(\lambda_1, \lambda_2^e) = 1 - \frac{\chi_n}{\lambda_1 + \lambda_2^e} \kappa(N_t^a, \Lambda_n, \theta)$$

- $\Pi_2(\lambda_1^a, \lambda_2^e)$ increasing in λ_1

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→ Entry of firms in one industry makes entry of the other industry more likely

- The linkage is stronger if
  - larger occupation overlap, $|S_1 \cap S_2|$
  - shared occupations used intensely (lower b_{n1} and b_{n2} for $n \in S_1 \cap S_2$)

details: overlap

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A measure of occupational overlap

Define similarity of industries i and j based on employees in common occupations

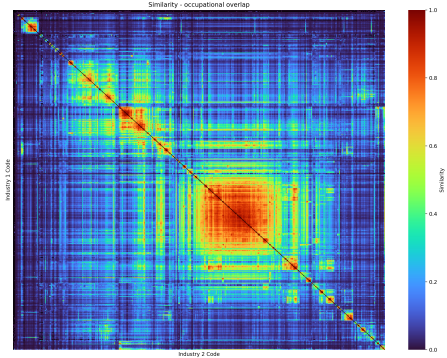
Cosine similarity

$$\text{COS}_{ij} = \frac{\sum_n l_{ni}\, l_{nj}}{\sqrt{\sum_n l_{ni}^2}\,\sqrt{\sum_n l_{nj}^2}}$$

- l_{ni}: count of workers in occupation n employed by industry i
- COS_{ij} larger if more occupational overlap and more workers in common occupations
- Compute this for a benchmark region (São Paulo, 2018)

task overlap

Industry Cosine Similarity Matrix: ordered by similarity



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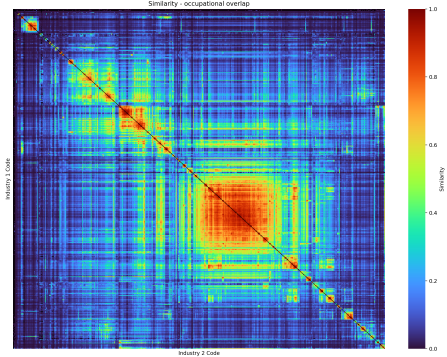

Industries with high overlap:

Retail sale of footwear and leather	Retail sale of clothing
Manufacture of cutlery	Manufacture of pens, pencils
Cattle farming	Sheep farming
Socks making	Tapestry
Buildings (residential, industrial, commercial services)	Incorporation, purchase and sale of real estate
Insecticide manufacturing	Manufacture of perfumery and cosmetics
Property management on behalf of third parties	Building condominiums
Processing and preservation of vegetables	Processing of meat, not slaughter

New industry entry potential

Define the **occupation-based entry potential** of (dormant) industry i in region r and year t as

$$P_{irt} = \sum_{j \neq i} COS_{ij} s_{jrt}$$

where s_{jrt} is the share of region r's workforce in industry j.

Empirical Strategy: Discrete-time hazard of industry entry

- Define active industries based on workforce: $Y_{irt} = \mathbb{I}[l_{irt} \geq 1]$
- keep only "at risk" observations
- model probability of entry with (lagged) entry potential, P_{irt}

$$Y_{irt} = \beta P_{ir,t-\tau} + \alpha_{rt} + \delta_{it} + \varepsilon_{irt}$$

- region and industry-specific baseline hazard rate control for
  - α_{rt}: regional aggregate demand spillovers
  - δ_{it}: industry-specific technology shocks

Result: Occupational linkage predicts industry entry

- Overlap in occupational requirement significantly increases entry prob. ($\hat{\beta} = 0.05$, $se = 0.006$) Table Logit version

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- 1 SD increase in P_{irt} increases entry probability by 15%
- Shifting P_{irt} from p25 $\rightarrow$ p75 increases entry probability by 20%

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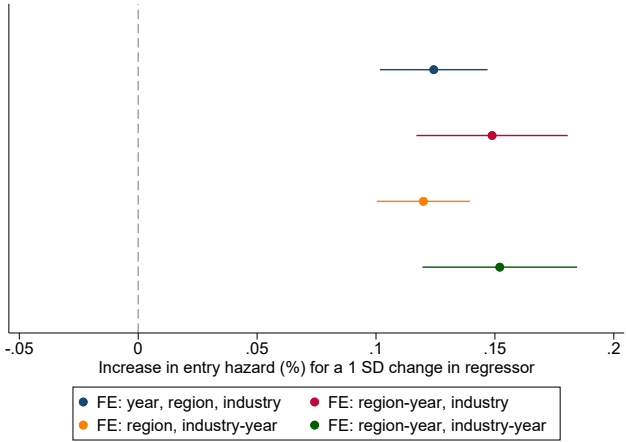


Overlap effect not driven by input-output linkages

Define IO-based entry index:

$$IO_{irt} = \sum_j \bar{IO}_{ij} s_{jrt}$$

Estimate:

$$Y_{irt} = \beta P_{ir,t-\tau} + \gamma IO_{ir,t-\tau} + \alpha_{rt} + \delta_{it} + \varepsilon_{irt}$$

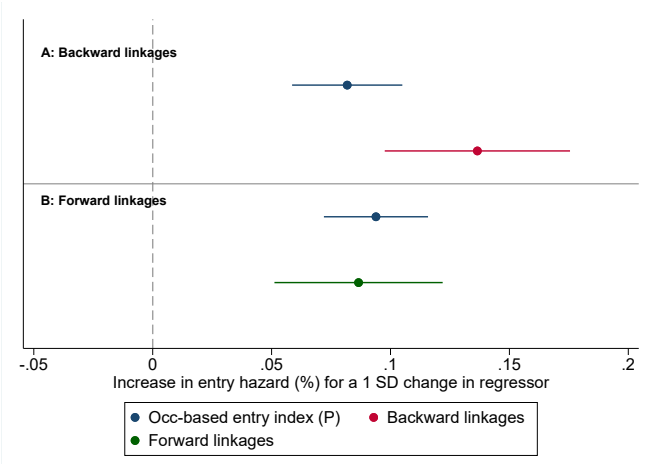


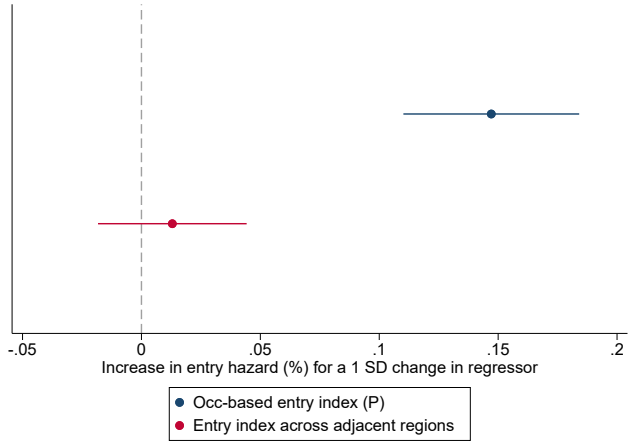
Table Logit

Not driven by migration from adjacent regions

Define occupation-index for adjacent regions:

$$P_{irt}^{\text{adjacent}} = \sum_{j \neq i} COS_{ij} s_{j\tilde{r}t}$$

where $s_{j\tilde{r}t}$ is industry j's share of the workforce of all regions adjacent to r



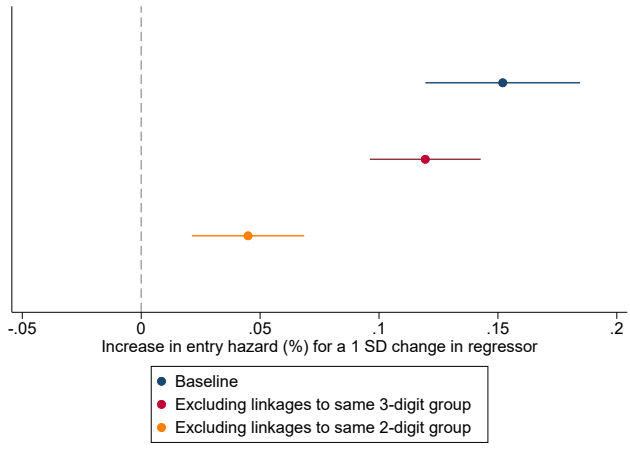
Table

Occupation linkages operate across industry groups

Define occupation-index excluding own industry group:

$$P_{irt}^{\text{across}} = \sum_{j \neq J_i} COS_{ij} s_{jrt}$$

where J_i denotes industries within the same 3- or 2-digit group as i.



Table

Shift-share instrument: Design

Potential endogeneity of entry potential index: $P_{irt} = \sum_j COS_{ij} \times s_{jrt}$

Instrument:

$$Z_{irt} = \sum_j COS_{ij} \times s_{jr,0} \times \Delta G_{jt}$$

- $s_{jr,0}$: initial share of region r's workforce in industry j
- ΔG_{jt}: aggregate shift in industry j
  - aggregate workforce in j (leaving out region r)
  - aggregate exports of j's products (leaving out r's exports)
  - imports of j's products by other countries (excluding Brazil)

Shift-share instrument: causal evidence for occupation linkages

	Dependent Variable: industry active (≥ 1 worker)		
	(1)	(2)	(3)
	agg. Employment	agg. Exports	Import shock
Panel A: First stage			
Instrument (L3)	1.213***	0.265***	0.000268***
	(0.132)	(0.0351)	(0.0000250)
Kleibergen–Paap F-stat	84.496	57.003	114.779
Panel B: Second stage (2SLS)			
Industry entry potential (L3)	0.0629***	0.0839***	0.0219*
	(0.00420)	(0.00785)	(0.00764)
N	2553606	2553606	2553606
FEregXt	YES	YES	YES
FEindXt	YES	YES	YES

- Similar magnitude to OLS estimates ($\hat{\beta} = 0.05$, $se = 0.006$)

Empirical Strategy 2: is growth path dependent?

Occupational structure should predict regional growth

$$\ln GRP_{r,t} = \alpha + \beta_1 \bar{P}_{r,t-\tau} + \beta_2 C_{r,t-\tau} + \beta_3 \ln GRP_{r,t-\tau} + \varepsilon_{rt}$$

- $GRP_{r,t}$ is gross regional product per capita
- $\bar{P}_{r,t-\tau}$ is occ-based entry potential aggregated to the region
- $C_{r,t-\tau}$ control for (aggregated) IO-based entry potential

Result 2: Aggregate linkages predict regional growth

	Dependent Variable: log GRP p/c					
	avg. all industries			avg. dormant industries		
	(1)	(2)	(3)	(4)	(5)	(6)
Entry potential (L5)	0.220***	0.167***	0.153***	0.146***	0.0909***	0.0912***
	(0.0196)	(0.0210)	(0.0204)	(0.0178)	(0.0182)	(0.0179)
Backward direct linkages (L5)		0.112***			0.0974***	
		(0.00914)			(0.00858)	
Forward direct linkages		-0.132***			-0.154***	
		(0.0129)			(0.0117)	
Backward total linkages (L5)			0.249***			0.138***
			(0.0203)			(0.0185)
Forward total linkages (L5)			-0.286***			-0.262***
			(0.0196)			(0.0180)
log GRP p/c (L5)	0.866***	0.816***	0.826***	0.880***	0.827***	0.843***
	(0.00402)	(0.00495)	(0.00475)	(0.00368)	(0.00477)	(0.00443)
Observations	6138	6138	6138	6138	6138	6138
R^2	0.908	0.913	0.912	0.908	0.912	0.911

Summary of empirical results

- Evidence of occupational linkages
  - 1 SD increase in occupation-based entry index, increases P of entry by 15%.
  - robust to shift-share specification using export shocks
  - robust to and IO-linkages and similar in magnitude
  - robust to correlated demand shocks within industry-groups table
  - positive, significant but small spillover effect from neighbouring regions
  - effect larger for services and industries using more occupations figure
- Aggregate linkages predict regional growth conditional on current GRP

Occ entry lags

Conclusion and policy implications

- Lack of specialised labour can hamper industrial policy
- Training/education and industrial policy are complements
- Target industries based on human capital spill-overs

Research agenda

Horizontal differentiation of labour in occupations raises many questions:

- This paper: How does occupational relate to industrial variety?
- Can variety contribute to aggregate productivity gains? How much?
- What's the cause of occupational variety?
  - Division of existing tasks (Smith) vs. new tasks (Ricardo)
  - How does task content of occupations change with development?

Thank You!

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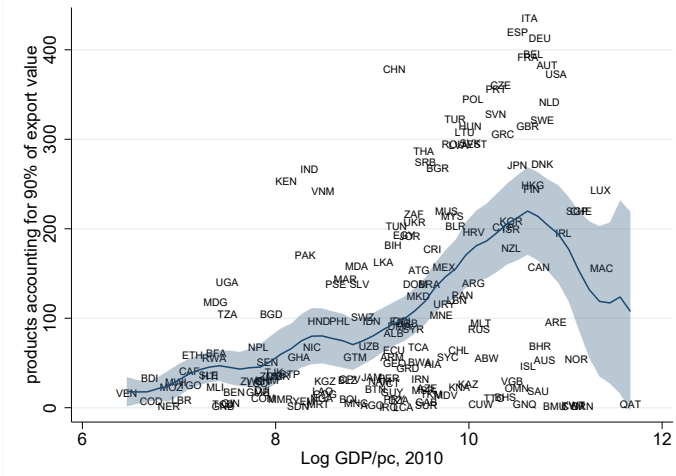
Variety of Exports



Source: CEPII, Penn World Tables back

Data: Occupation codes - example

Economists

251115	Cientista político
251120	Sociólogo
251205	Economista
251210	Economista agroindustrial
251215	Economista financeiro
251220	Economista industrial
251225	Economista do setor público
251230	Economista ambiental
251235	Economista regional e urbano
251305	Geógrafo
251405	Filósofo

Tobacco manufacturing

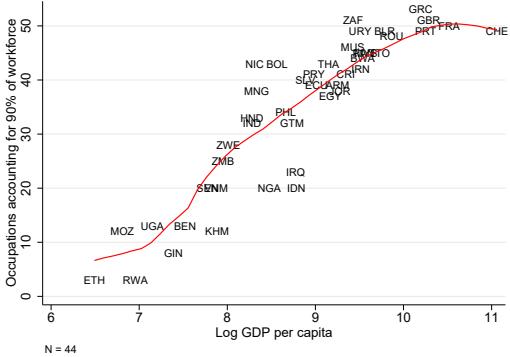
842105	Preparador de melado e essência de fumo
842110	Processador de fumo
842115	Classificador de fumo
842120	Auxiliar de processamento de fumo
842125	Operador de máquina (fabricação de cigarros)
842135	Operador de máquina de preparação de matéria prima para produção de cigarros
842205	Preparador de fumo na fabricação de charutos
842210	Operador de máquina de fabricar charutos e cigarrilhas
842215	Classificador de charutos
842220	Cortador de charutos
842225	Celofanista na fabricação de charutos
842230	Charuteiro a mão
842235	Degustador de charutos

More Tasks 1 Tasks 2 Tasks/Occ

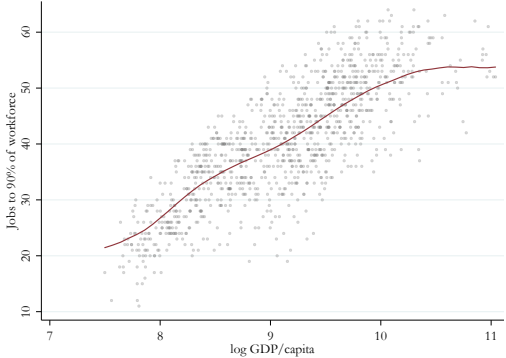
back

Why Brazil 1

Regional variation in Brazil mirrors cross-country patterns



(a) Cross-country



(b) Brazil

- Data from 2010 Population Census, IBGE

Data: Occupation codes - horizontal differentiation

Back

Language Teachers

234604	Professor de língua alemã
234608	Professor de língua italiana
234612	Professor de língua francesa
234616	Professor de língua inglesa
234620	Professor de língua espanhola
234624	Professor de língua portuguesa
234628	Professor de literatura brasileira
234632	Professor de literatura portuguesa
234636	Professor de literatura alemã
234640	Professor de literatura comparada
234644	Professor de literatura espanhola
234648	Professor de literatura francesa
234652	Professor de literatura inglesa
234656	Professor de literatura italiana

Referees

377140	Profissional de atletismo
377145	Pugilista
377205	Árbitro desportivo
377210	Árbitro de atletismo
377215	Árbitro de basquete
377220	Árbitro de futebol
377225	Árbitro de futebol de salão
377230	Árbitro de judô
377235	Árbitro de karatê
377240	Árbitro de poló aquático
377245	Árbitro de vôlei
391105	Cronoanalista
391110	Cronometrista
391115	Controlador de entrada e saída
391120	Planejista

Data: Economist's tasks

Back

251205	Analisar conjunturas
251205	Realizar análises setoriais e regionais
251205	Analisar ambiente político-institucional
251205	Analisar sustentabilidade socio-econômica e ambiental
251205	Analisar tendências de longo prazo
251205	Construir cenários
251205	Gerenciar bancos de dados
251205	Delinear problema
251205	Delimitar objeto
251205	Justificar projeto
251205	Levantar bibliografia
251205	Definir metodologia
251205	Determinar fontes
251205	Definir produtos e resultados
251205	Dimensionar recursos humanos e físicos
251205	Definir cronograma
251205	Orçar projetos
251205	Negociar projetos
251205	Recrutar equipe
251205	Treinar equipe
251205	Coordenar projetos
251205	Desenvolver instrumentos de coleta
251205	Coletar dados
251205	Processar dados
251205	Criticar dados
251205	Desenvolver indicadores
251205	Interpretar resultados
251205	Propor ações
251205	Identificar estrutura de mercado (concorrência)
251205	Prever atuação dos concorrentes
251205	Identificar oportunidades e ameaças no ambiente e na organização
251205	Estimar demanda

251205	Elencar alternativas de ação
251205	Estimar custos privados
251205	Estimar impactos sociais e ambientais (externalidades)
251205	Estimar resultados
251205	Estimar rentabilidade e viabilidade econômico-financeira
251205	Sugerir adoção de tecnologia
251205	Planejar investimentos (orçamentos de capital)
251205	Selecionar fontes de financiamento
251205	Gerar parâmetros de avaliação
251205	Aferir adequação das ações ao problema
251205	Verificar execução das ações propostas
251205	Mensurar consequências das ações
251205	Confrontar com custos alternativos
251205	Recomendar políticas
251205	Acompanhar indicadores de mercado
251205	Acompanhar execução orçamentária
251205	Auxiliar na formulação de políticas comerciais
251205	Auxiliar em políticas de marketing
251205	Detectar novos mercados
251205	Precificar produtos e serviços
251205	Subsidiar formulação de normas, regulamentos e contratos
251205	Representar interesses em negociações nacionais e internacionais
251205	Averiguar barreiras à competição
251205	Averiguar vantagens comparativas
251205	Calcular valor de mercado da empresa
251205	Verificar informações da empresa (due diligence)
251205	Efetuar análise de demonstrativo financeiro
251205	Indicar fusão, aquisição, parceria etc
251205	Efetuar análise de crédito
251205	Emitir laudos e pareceres
251205	Valorar patrimônio
251205	Mediar conflitos de interesse

251205	Estabelecer sentença arbitral
251205	Escrever artigos, livros, boletins econômicos e relatórios
251205	Proferir palestras
251205	Apresentar comunicações em eventos
251205	Dialogar com a mídia
251205	Adaptar linguagem ao público
251205	Ministrar cursos
251205	Manter-se atualizado
251205	Subsidiar decisões
251205	Trabalhar em equipe
251205	Transmitir conhecimentos
251205	Demonstrar capacidade de liderança
251205	Demonstrar capacidade de uso de recursos de informática
251205	Revelar julgamento crítico
251205	Formular conceitos abstratos
251205	Demonstrar raciocínio lógico
251205	Mostrar criatividade
251205	Aplicar métodos quantitativos
251205	Demonstrar capacidade verbal línguas estrangeiras

Data: Cigar taster's tasks

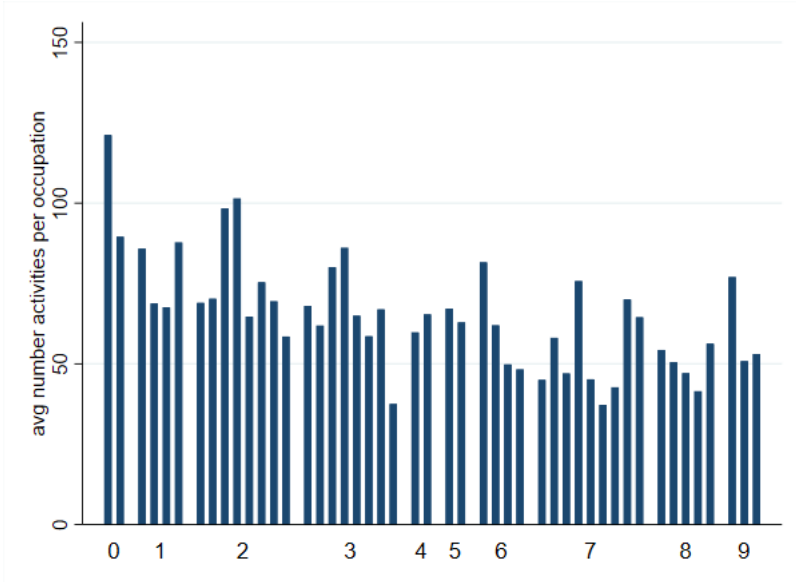
Back

842235	Congelar folhas de fumo
842235	Classificar fumo
842235	Umedecer fumo
842235	Destalar fumo
842235	Desfiar fumo
842235	Cortar fumo
842235	Secar fumo
842235	Aromatizar mistura de fumo
842235	Misturar tabaco
842235	Encher charutos e cigarrilhas
842235	Enrolar charutos e cigarrilhas
842235	Cortar extremidades de charutos e cigarrilhas
842235	Enformar charutos
842235	Prensar charutos
842235	Medir dimensões de charutos e cigarrilhas
842235	Verificar textura e peso de charutos e cigarrilhas
842235	Conferir uniformidade de charutos e cigarrilhas
842235	Vistoriar acabamento de bicos de charutos e cigarrilha
842235	Inspecionar capeamento de charutos e cigarrilhas
842235	Registrar produção individual de charutos e cigarrilhas
842235	Revisar embalagens de charutos e cigarrilhas
842235	Degustar charutos e cigarrilhas
842235	Dar forma nos bicos de charutos e cigarrilhas
842235	Capear charutos e cigarrilhas
842235	Cortar charutos e cigarrilhas
842235	Classificar charutos e cigarrilhas
842235	Modelar charutos e cigarrilhas
842235	Aromatizar cigarrilhas e charutos
842235	Congelar charutos e cigarrilhas
842235	Desumidificar charutos e cigarrilhas
842235	Estocar charutos e cigarrilhas
842235	Controlar ambiente (temperatura e umidade)

842235	Instalar armadilhas contra insetos
842235	Anelar charutos e cigarrilhas
842235	Celofanar charutos e cigarrilhas
842235	Personalizar charutos e cigarrilhas
842235	Acondicionar charutos e cigarrilhas
842235	Rotular embalagens
842235	Plastificar caixas
842235	Demonstrar habilidade manual
842235	Manifestar sensibilidade tátil
842235	Dar provas de acuidade visual
842235	Evidenciar pré-disposição para atividades de rotina
842235	Demonstrar flexibilidade
842235	Dar provas de capacidade de concentração
842235	Evidenciar comprometimento com o trabalho

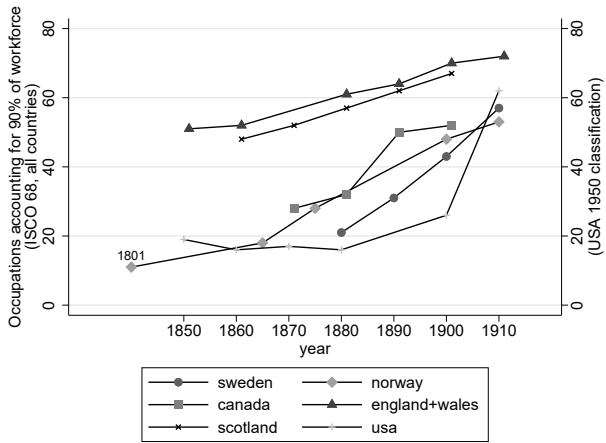
Data: Tasks by occupation group

Back



Occupational variety grows with development

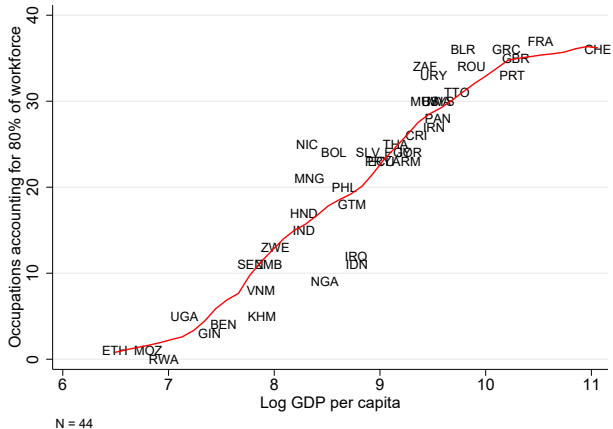
over time



Source: IPUMS historical censuses back

Robustness: Occupational variety grows with development

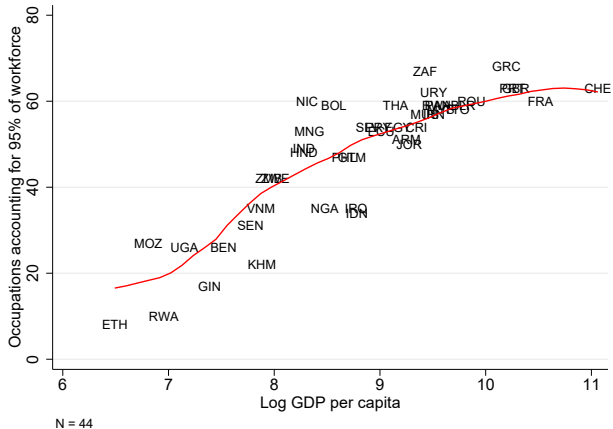
Occupations accounting for 80% of workforce



back

Robustness: Occupational variety grows with development

Occupations accounting for 95% of workforce

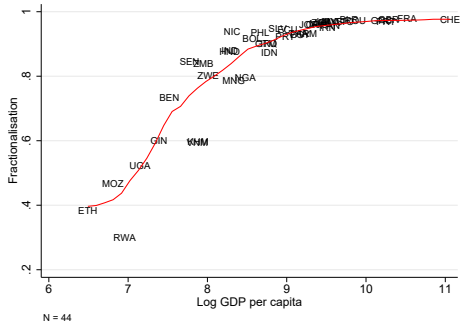


back

Robustness: Occupational variety grows with development

Fractionalisation index

back

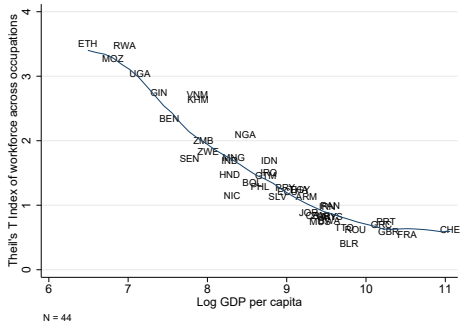


$$\text{Frac}_i = 1 - HHI_i = 1 - \sum_{n=1}^{N} s_{ni}^2$$

Robustness: Occupational variety grows with development

Theil's T index

back



$$T_i = \frac{1}{N_i} \sum_{n=1}^{N} \frac{l_{ni}}{\mu_i} \ln\left(\frac{l_{ni}}{\mu_i}\right)$$

Occupational variety as structural transformation

How does occupational variety interact with other structural transformations?

- Human capital (Mankiw et al. (1992), Buera and Kaboski (2012), and Porzio et al. (2022))
- Sectoral composition (e.g. Herrendorf et al. (2014))
- Urbanisation (e.g. Bryan et al. (2020))
- Women's labour force participation (e.g. Ngai and Petrongolo (2017))
- Emergence of wage work in firms (e.g. Jensen (2022) and Bandiera et al. (2022))
- Industrial diversification (Imbs and Wacziarg (2003))

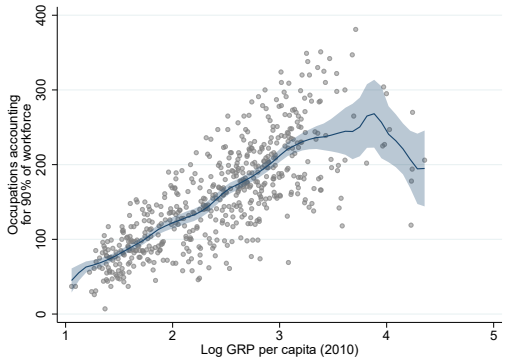
Use census micro-data to analyse occupations within sub-groups of the workforce

→ Occ - GDP relationship not fully accounted for by other transformations

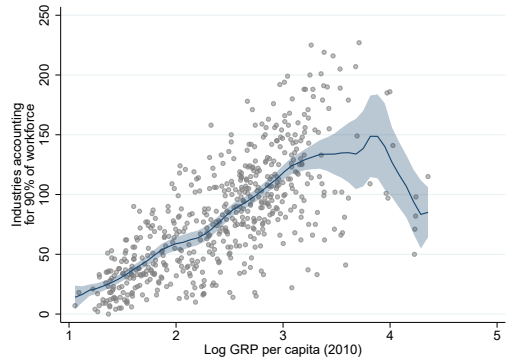
Occupational variety grows with development

... across regions within Brazil

(a) Occupational variety

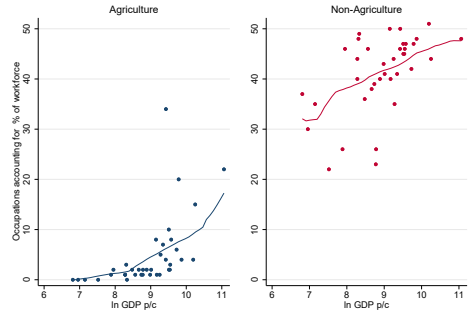


(b) Industrial variety



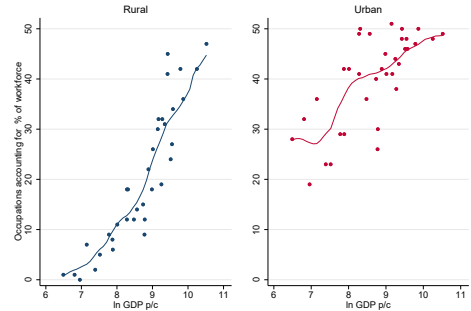
Census

(a) Sectoral change



N = 44

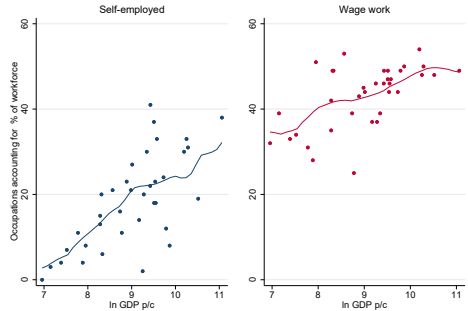
(b) Urbanisation



N = 44

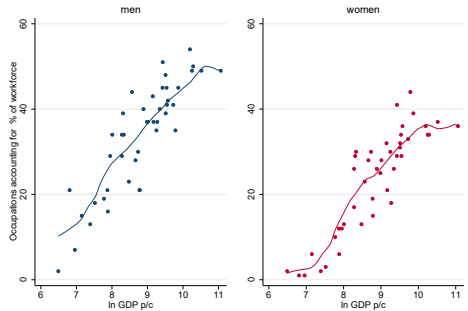
back by ISCO1 by Agriculture by Urban

(a) Firms



N = 36

(b) Gender



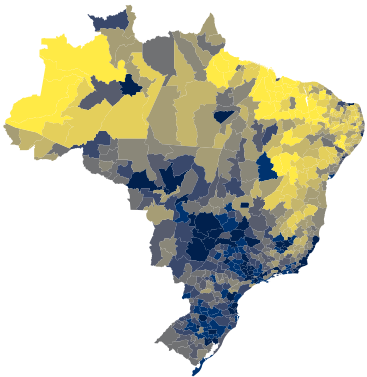
N = 44

by ISCO1 | by Gender | by Employment

Brazil: occupational variety across regions

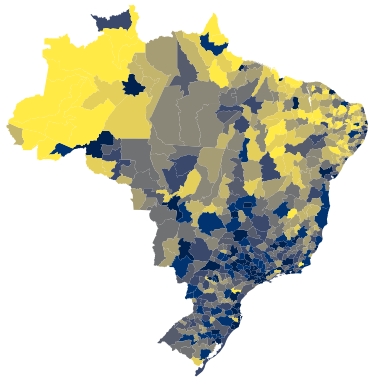
GDP per capita

real, 2010 BRL



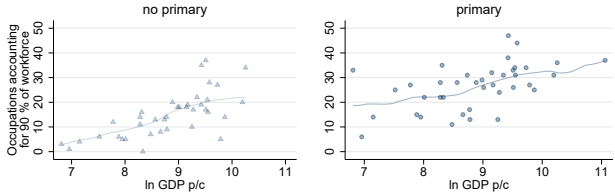
Number of occupations

6−digit codes, CBO



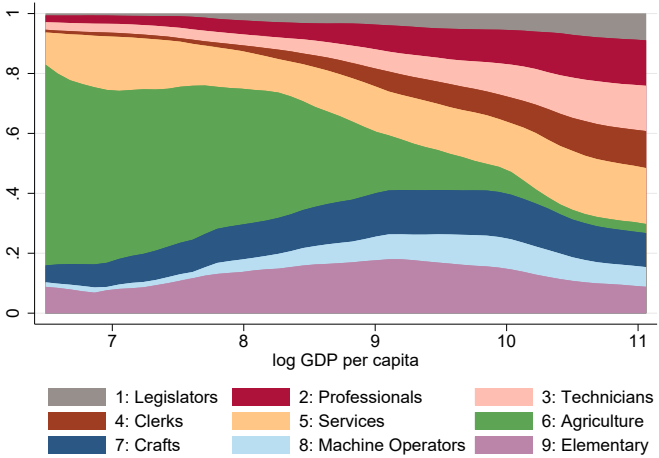
Back

by Education



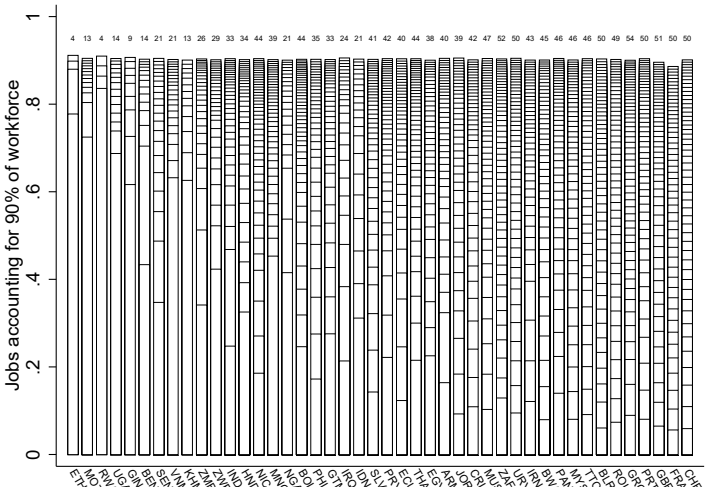
N = 39

By ISCO-1 digit

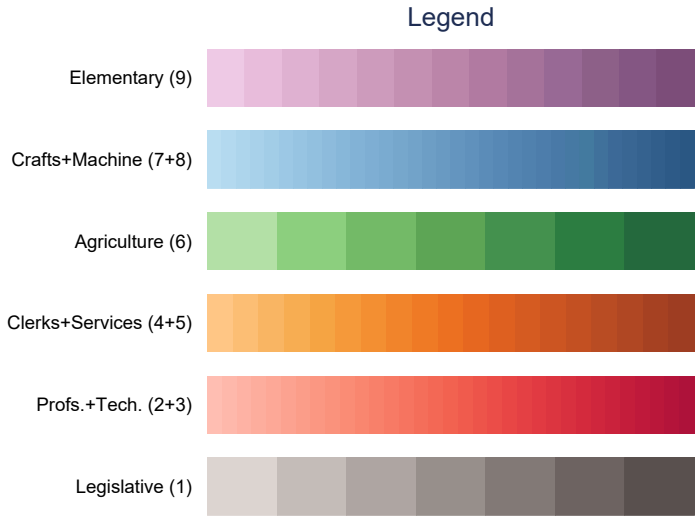


back

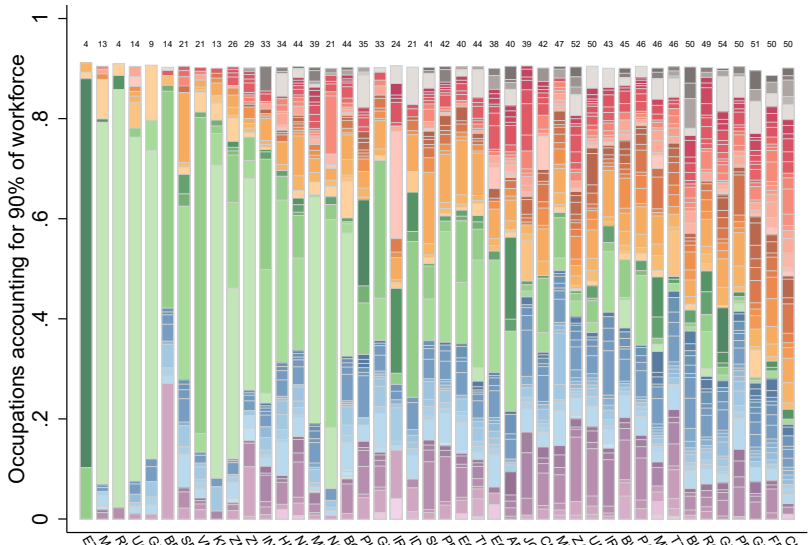
Stack frequency



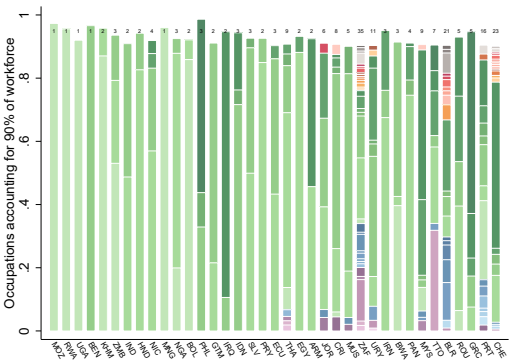
Now colour occupations by ISCO-1 and average skill

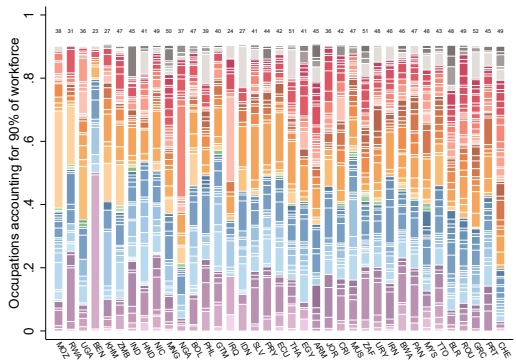


By ISCO-1 digit, frequency and skill intensity



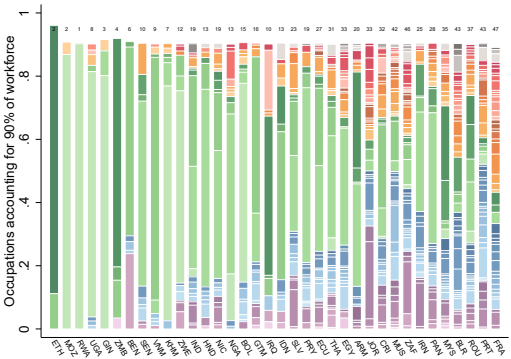
By Agriculture vs. Non-agriculture

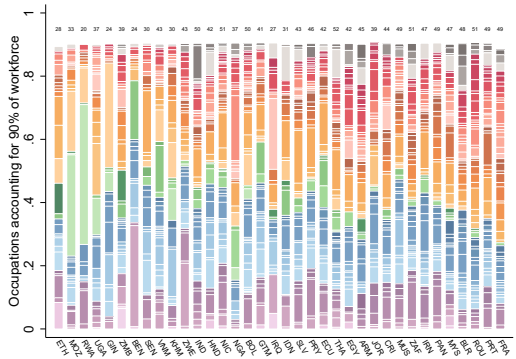




back

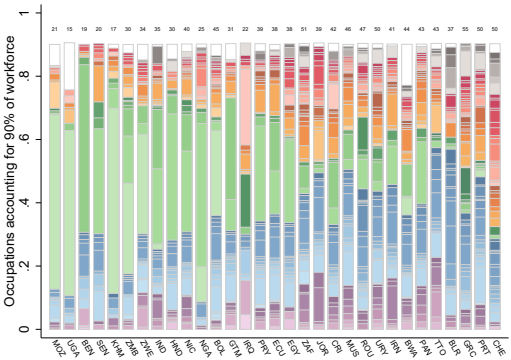
Rural vs. Urban 2

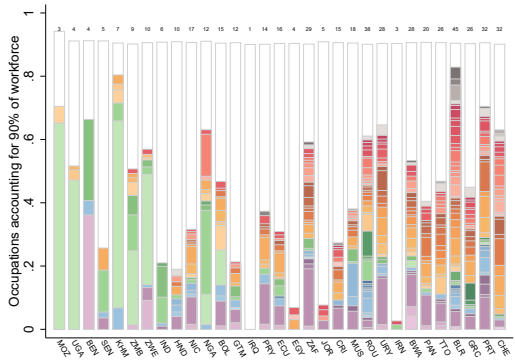




back

Men vs. Women





back

Occupations and income: micro-regions

$$\ln Occ_{rt} = \alpha + \beta_1 \ln GDP_{rt} + \beta_2 C_{rt} + \delta_t + \pi_r + e_{rt}$$

	Dependent Variable: Log count of unique occupations (6-digit CBO)				
	(1)	(2)	(3)	(4)	(5)
Log GDP p/c	0.646***	0.600***	0.604***	0.435***	0.138***
	(0.00848)	(0.00837)	(0.00863)	(0.00800)	(0.00913)
Controls	NO	YES	YES	YES	YES
year FE	NO	NO	YES	NO	YES
region FE	NO	NO	NO	YES	YES
Observations	8928	8928	8928	8928	8928
R^2	0.481	0.537	0.537	0.979	0.984

back

Occupations and income: micro-regions

back

$$\ln Occ_{rt} = \alpha + \beta_1 \ln GDP_{rt} + \beta_2 \ln Ind_{rt} + \beta_3 C_{rt} + \delta_t + \pi_r + e_{rt}$$

	Dependent Variable: Log count of unique occupations (6-digit CBO)				
	(1)	(2)	(3)	(4)	(5)
Log GDP p/c	0.600***	0.0522***	0.0441***	0.146***	0.0645***
	(0.00837)	(0.00316)	(0.00323)	(0.00679)	(0.00642)
Log unique industries		0.908***	0.910***	0.778***	0.691***
		(0.00572)	(0.00566)	(0.0184)	(0.0220)
Controls	YES	YES	YES	YES	YES
year FE	NO	NO	YES	NO	YES
region FE	NO	NO	NO	YES	YES
Observations	8928	8928	8928	8928	8928
R^2	0.537	0.958	0.959	0.990	0.991

Regions with more occupations have more industries

$$Occ_{rt} = \alpha + \beta Ind_{rt} + \gamma C_{rt} + \delta_t + \pi_r + e_{rt}$$

	Dependent Variable: unique occupations			
	(1)	(2)	(3)	(4)
unique industries	3.686***	3.702***	2.545***	1.492***
	(0.0159)	(0.0159)	(0.0473)	(0.0431)
Controls	YES	YES	YES	YES
year FE	NO	YES	NO	YES
region FE	NO	NO	YES	YES
Observations	8928	8928	8928	8928
R^2	0.970	0.971	0.996	0.997

back

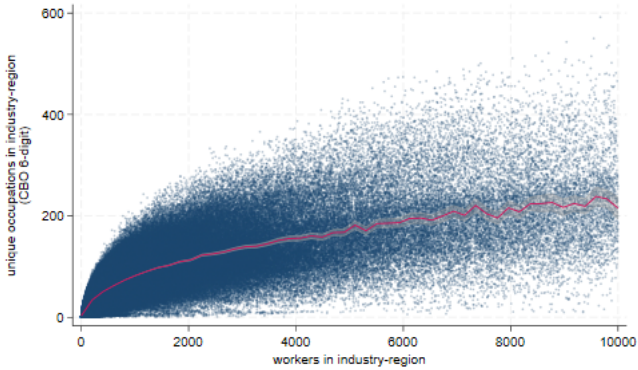
Growth in Occupations: Microregion-by-industries

back

$$\ln Occ_{irt} = \alpha + \beta \ln Emp_{irt} + \delta_t + \pi_r + \gamma_i + e_{irt}$$

	Dependent Variable: log # distinct occupations (6-digit CBO)			
	(1)	(2)	(3)	(4)
Log # employees	0.617***	0.600***	0.605***	0.603***
	(0.000135)	(0.000143)	(0.000185)	(0.000187)
yearFE	NO	YES	NO	YES
regionFE	NO	YES	YES	YES
industryFE	NO	NO	YES	YES
Observations	2278147	2278147	2278143	2278143
R^2	0.899	0.903	0.934	0.934

Occupational specialisation occurs within industries



- Decomposition: 10-30% of new occupations enter with new industry

Table Decomp. details back

Decomposing entry of new occupations by industry (1) back

For any region and any two time periods t_0 and t_1

- Decompose new occupations, $S^{new} = S_1 \setminus S_0$, into those that appear
  - in existing industries, $K^{cont} = K_0 \cap K_1$
  - in new industries $K^{new} = K_1 \setminus K_0$

The same occupation can be employed in multiple industries

- let S_{kt} set of occupations in industry k in t
- and $\tilde{S}_k^{new} = S_{k1} \cap S^{new} = S_{k1} \setminus S_0$ the set of genuinely new occupations in k
- For $n \in S^{new}$ define $K_n = \{k \in K_1 : n \in S_{k1}\}$ the set of industries in which n is employed

Then

$$W^+ = \sum_{k \in K^{cont}} \sum_{n \in \tilde{S}_k^{new}} \frac{1}{|K_n|} \qquad \text{and} \qquad A^+ = \sum_{k \in K^{new}} \sum_{n \in \tilde{S}_k^{new}} \frac{1}{|K_n|}$$

Decomposing entry of new occupations by industry (2)

Analogously for occupations that disappear between t_0 and t_1:

$$W^- = \sum_{k \in K^{cont}} \sum_{n \in \tilde{S}_k^{drop}} \frac{1}{|K_n|} \qquad \text{and} \qquad A^- = \sum_{k \in K^{drop}} \sum_{n \in \tilde{S}_k^{drop}} \frac{1}{|K_n|}$$

Then the change in the number of unique occupations can be decomposed into

$$\Delta N = (W^+ - W^-) + (A^+ - A^-) \tag{1}$$

- The first bracket captures net new occupations within existing industries
- The second bracket captures net new occupations in new industries

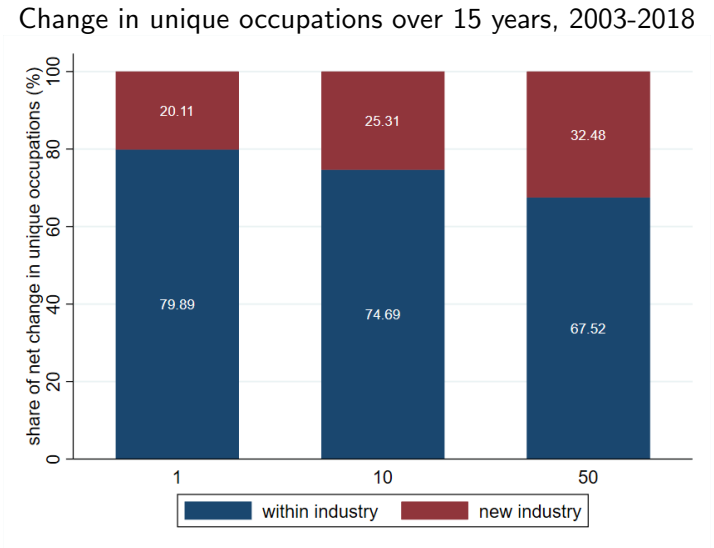
Decomposition Results: year-to-year

Sample average of year-to-year changes:

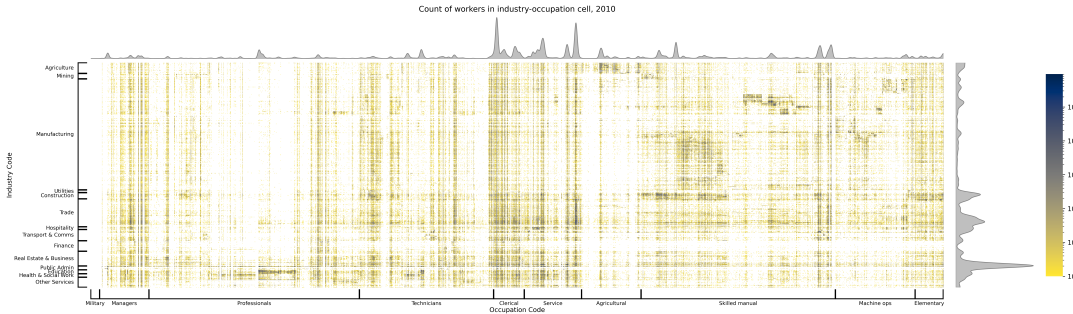
$$\Delta N = \underbrace{(W^+ - W^-)}_{\text{W}} + \underbrace{(A^+ - A^-)}_{\text{A}}$$

$$10.47 = \quad 9.57 \quad + \quad 0.90$$

Decomposition Results: long distance



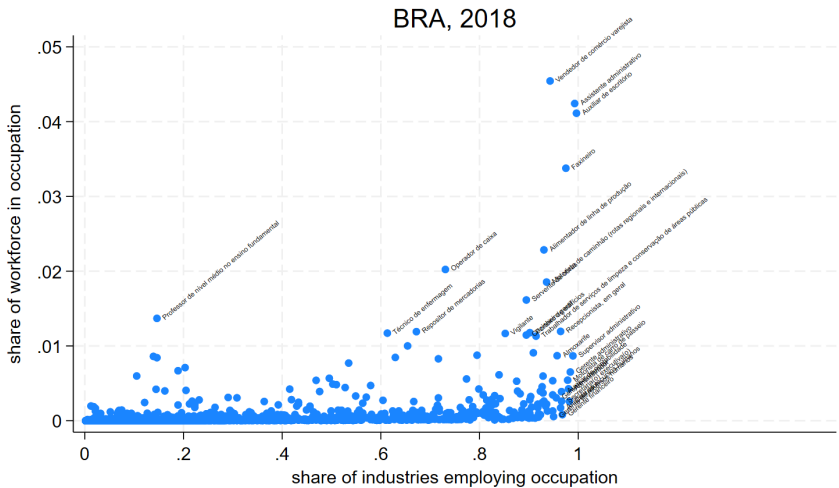
Industrial linkages through common occupations - Heatmap



occ-size scatter back

Occupations employed in multiple industries - by occupation size

back



Occupational Choice - Details

Assume $a_n(\omega) \overset{\text{iid}}{\sim} \text{Fréchet}(1, \theta)$, with $\theta > 1$

Labour shares:

$$L_n^S(w_n, \pi_n) = Pr\{n = \text{argmax } U_n(\omega)\} = \frac{(\pi_n w_n)^\theta \chi_n^{-\theta}}{\bar{u}^\theta + \sum_{s=1}^N (\pi_s w_s)^\theta \chi_s^{-\theta}} \equiv \frac{(\pi_n w_n)^\theta \chi_n^{-\theta}}{\Phi}$$

Average productivity:

$$\bar{a}_n(w_n, \pi_n) = \mathbb{E}\left[a_{in} \middle| i : n = \text{argmax}_{n \in \mathcal{N}}\{U_{in}\}\right] = \Gamma\left(1 - \frac{1}{\theta}\right) \frac{\chi_n}{\pi_n w_n} \Phi^{\frac{1}{\theta}}$$

$\Gamma(\cdot)$ denotes the gamma function - treat as a constant, $\gamma(\theta)$

back

Result: more occupations : more effective labour

Assume symmetry: $w_n = w$ and $\chi_n = \chi, \forall n$

Effective labour in each *active* occupation:

$$\tilde{L} = \gamma(\theta) \frac{\left(\frac{w}{\chi}\right)^{\theta-1}}{\left[\bar{u}^{\theta} + N\left(\frac{w}{\chi}\right)^{\theta}\right]^{1-\frac{1}{\theta}}}.$$

Then $\frac{d[N\tilde{L}(N)]}{dN} > 0$

Larger number of occupations increases productivity because

1. better allocation of worker that train
2. fewer workers chose no training and subsistence (Lewis et al. (1954))

back

Labour market clearing back

Labour supply (from occupational choice):

$$\tilde{L}_n^S(w_n, \pi_n) = \left(\frac{\pi_n w_n}{\chi_n}\right)^{\theta-1} \frac{\gamma(\theta)}{\Phi^{1-\frac{1}{\theta}}}$$

Labour demand (from firm entry):

$$\tilde{L}_{n,t}^D(\lambda(w)) = \sum_{i:n\in S_i} \frac{\lambda_{i,t}(w)}{b_{n,i}}$$

Market clearing condition:

$$\begin{aligned}\tilde{L}_n^D(\lambda(w)) &= \pi_n \tilde{L}_n^S(w_n, \pi_n) \\ &= \pi_n \left(\frac{\pi_n w_n}{\chi_n}\right)^{\theta-1} \frac{\gamma(\theta)}{\Phi^{1-\frac{1}{\theta}}}\end{aligned}$$

Within-period entry equilibrium back

- at the beginning of t, λ_{it} and implied N_t^a are known
- workers draw talents $a_n(\omega)$ and dormant firms fixed costs $F(k)$
- within-period equilibrium: entry shares λ_t^e, hiring probabilities π_n, and wages w_n
- given entry shares, can solve π_n and w_n
- entry in industry i as a function of all other entry $\boldsymbol{\lambda}_t^e$:

$$\mathcal{T}_i(\boldsymbol{\lambda}_t^e) = H\left[1 - c_i(w(\boldsymbol{\lambda}_t^e))\right]$$

- Equilibrium as a fixed point of $\mathcal{T}(\cdot)$
- At the end of t, new entrants join next period's active firms: $\lambda_{l,t+1}^a = \lambda_{l,t}^a + \lambda_{l,t}^d$

Stagnation and entry

back

Consider 1 dormant industry that hires 1 occupation:

- Entry probability for any one firm is $H_F(1 - c_i)$ with

$$1 - c_i = 1 - \frac{\chi_n}{\lambda_{i,t}} \left(\frac{\Lambda_n}{b_{ni}\gamma(\theta)} \right)^{\frac{\theta+1}{\theta-1}} \Phi^{\frac{1}{\theta}}$$

- Entry more likely if
  - larger mass of already active firms or expected entrants ($\lambda_{i,t}$)
  - n has high return in i (b_{ni})
  - lower training cost χ_n
  - fewer potential firms compete for n (Λ_n) or other occupations for workers ($f\Phi$)
- No entry if $c_i > 1$: expensive bottleneck occupation can hold up entry
- Entry triggers further entry : λ_i converges to 1

Result: Occupation based linkage between industries

Consider 2 industries that hire the same occupation:

- Industry 1: active with $\lambda_1^a > 0$
- Industry 2: dormant
- Firm in 2 considering entry has operating profits:

$$\Pi_2(\lambda_1^a, \lambda_2^e) = 1 - \frac{\chi_n}{\lambda_1^a + \lambda_2^e} \kappa(N_t^a, \Lambda_n, \theta) \tag{2}$$

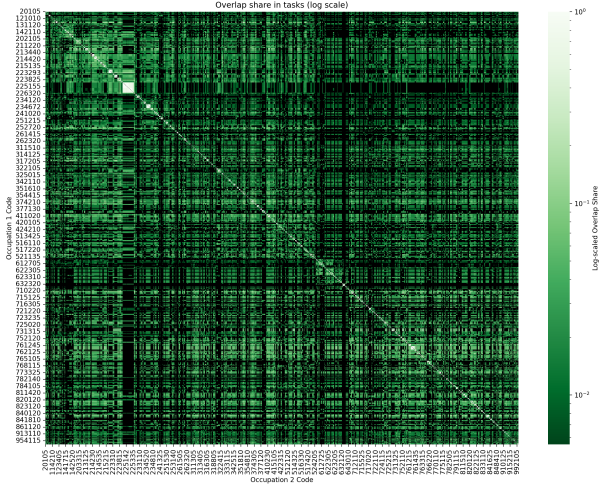
- $\Pi_2(\lambda_1^a, \lambda_2^e)$ increasing in λ_1

➔ Entry of firms in one industry makes entry in the other industry more likely

- The linkage is stronger if
  - larger occupation overlap, $|S_1 \cap S_2|$
  - shared occupations used intensely (lower b_{n1} and b_{n2} for $n \in S_1 \cap S_2$)

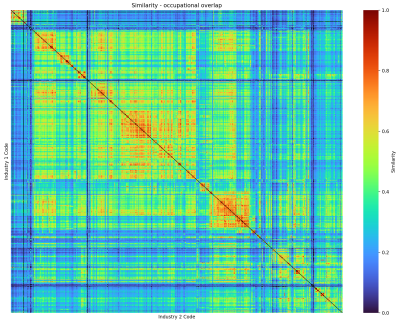
back

Occupations similarity based on tasks

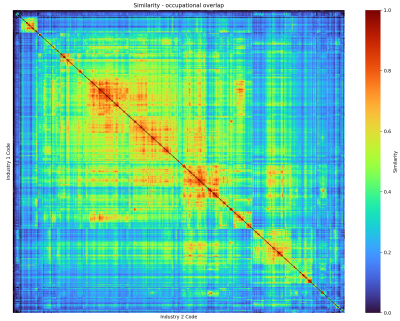


back

Bhattacharyya Coefficient Matrix



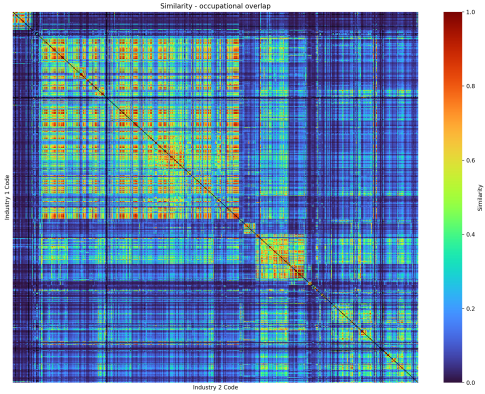
(a) Ordered by industry ID



(b) Ordered by similarity

Cosine

Industry Cosine Similarity Matrix: Ordered by broad sector



Result: Occupational linkage predicts industry entry

	Dependent variable: industry active ($\geq$1 worker			
	(1)	(2)	(3)	(4)
Industry entry potential (L3)	0.0412***	0.0494***	0.0398***	0.0504***
	(0.00383)	(0.00539)	(0.00331)	(0.00550)
N	2553678	2553677	2553607	2553606
FEt	YES	NO	NO	NO
FEr	YES	NO	YES	NO
FEi	YES	YES	NO	NO
FEregXt	NO	YES	NO	YES
FEindXt	NO	NO	YES	YES

Back

Logit: Occupational overlap predicts industry entry

	Dependent variable: industry active ($\geq$ 1 worker)			
	(1)	(2)	(3)	(4)
Entry potential index	0.05***	0.06***	0.05***	0.06***
	(0.00)	(0.00)	(0.00)	(0.00)
Time-at-risk (t) FE	YES	NO	NO	NO
Industry FE	YES	NO	YES	NO
Region FE	YES	YES	NO	NO
Industry$\times$t FE	NO	YES	NO	YES
Region$\times$t FE	NO	NO	YES	YES
Observations	2177172	2134470	1910486	1875134

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

- Magnitude: shifting P_{irt} from p25 $\rightarrow$ p75 increases entry probability by 30%

Result: Overlap effect not driven by input-output linkages

	Dependent variable: number workers in industry-region						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Industry entry potential (L3)	0.0504***	0.0398***	0.0558***	0.0534***	0.0267***	0.0306***	0.0364***
	(0.00550)	(0.00449)	(0.00423)	(0.00404)	(0.00386)	(0.00364)	(0.00372)
Direct backward linkages (L3)		0.0869***		0.103***			
		(0.0172)		(0.0167)			
Direct forward linkages (L3)			-0.176***	-0.179***			
			(0.0154)	(0.0152)			
Total backward linkages (L3)					0.0457***		0.162***
					(0.00665)		(0.0116)
Total forward linkages (L3)						0.0286***	-0.123***
						(0.00596)	(0.00868)
N	2553606	2415658	2415658	2415658	2415658	2415658	2415658
FEregXt	YES	YES	YES	YES	YES	YES	YES
FEindXt	YES	YES	YES	YES	YES	YES	YES

Back

Logit: Overlap effect not driven by input-output linkages

	Dependent variable: industry active ($\geq$ 1 worker)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Entry potential index (L5)	0.056***	0.052***	0.053***	0.052***	0.043***	0.043***	0.043***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Direct Backward Linkages (L5)		0.072***		0.072***			
		(0.013)		(0.013)			
Direct Forward Linkages (L5)			−0.001	−0.006			
			(0.010)	(0.011)			
Total Backward Linkages (L5)					0.028***		0.039***
					(0.002)		(0.007)
Total Forward Linkages (L5)						0.024***	−0.012
						(0.003)	(0.008)
Industry × year FE	YES	YES	YES	YES	YES	YES	YES
Region × year FE	YES	YES	YES	YES	YES	YES	YES
Observations	1875134	1749770	1749770	1749770	1749770	1749770	1749770

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

back

Not driven by correlated demand shocks

	Dependent variable: industry active ($\geq$1 worker)					
	5-digit		3-digit		2-digit	
	(1)	(2)	(3)	(4)	(5)	(6)
Entry Potential (L3)	0.0504***	0.0365***	0.0399***	0.0304***	0.0153***	0.0188***
	(0.00393)	(0.00403)	(0.00398)	(0.00405)	(0.00411)	(0.00413)
Total backward linkages (L3)		0.162***		0.163***		0.162***
		(0.00816)		(0.00816)		(0.00811)
Total forward linkages (L3)		-0.123***		-0.120***		-0.115***
		(0.00792)		(0.00791)		(0.00785)
N	2553606	2415658	2553606	2415658	2553606	2415658

back

Robustness: spillovers on neighbouring regions

	Dependent variable: number workers in industry-region						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Industry entry potential (L3)	0.0488***	0.0365***	0.0516***	0.0493***	0.0233***	0.0274***	0.0324***
	(0.00626)	(0.00441)	(0.00433)	(0.00416)	(0.00372)	(0.00356)	(0.00372)
P in adjacent regions (L3)	0.00447	0.00883	0.0112*	0.0112*	0.00885	0.00850	0.0105*
	(0.00548)	(0.00468)	(0.00459)	(0.00461)	(0.00474)	(0.00471)	(0.00471)
Direct backward linkages (L3)		0.0869***		0.103***			
		(0.0172)		(0.0167)			
Direct forward linkages (L3)			-0.176***	-0.180***			
			(0.0154)	(0.0152)			
Total backward linkages (L3)					0.0457***		0.163***
					(0.00664)		(0.0116)
Total forward linkages (L3)						0.0285***	-0.123***
						(0.00595)	(0.00863)
N	2553606	2415658	2415658	2415658	2415658	2415658	2415658
FEregXt	YES	YES	YES	YES	YES	YES	YES
FEindXt	YES	YES	YES	YES	YES	YES	YES

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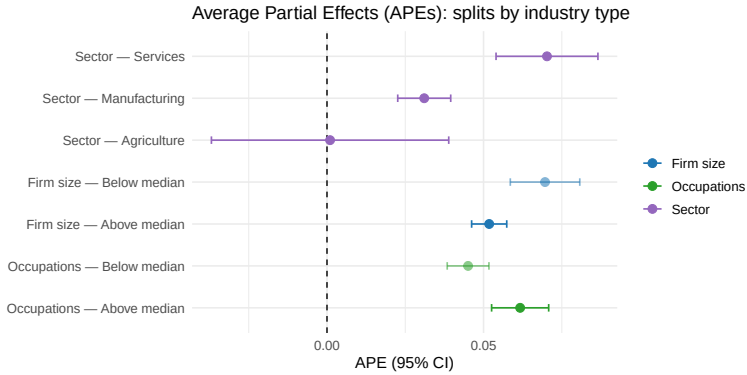
Heterogeneity by industry type



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Occupation entry

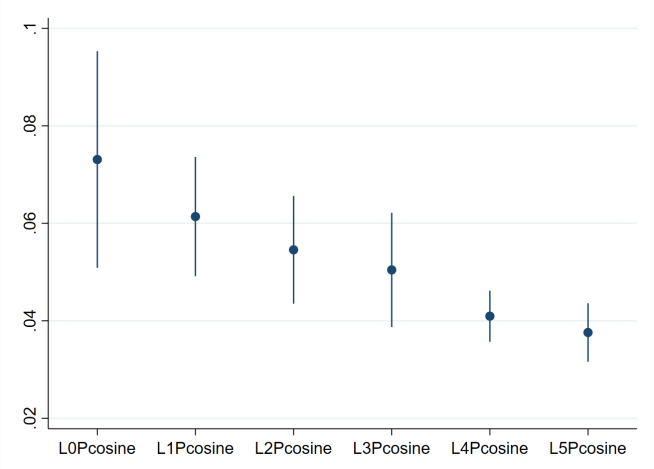
Occupation entry index: $O_{nrt} = \sum_j P_{jrt}\bar{s}_{nj}$

	Dependent variable: occupation active (≥ 1 worker)			
	(1)	(2)	(3)	(4)
Occupation entry potential	0.02***	0.02***	0.08***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)
Time-at-risk (t) FE	YES	NO	NO	NO
Occupation FE	YES	NO	YES	NO
Region FE	YES	YES	NO	NO
Occupation $\times$ t FE	NO	YES	NO	YES
Region $\times$ t FE	NO	NO	YES	YES
Observations	9866189	9866189	9866189	9866189

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

back

Different lags, entry hazard with LPM link



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