Automation, Globalization and Vanishing Jobs:

A Labor Market Sorting View

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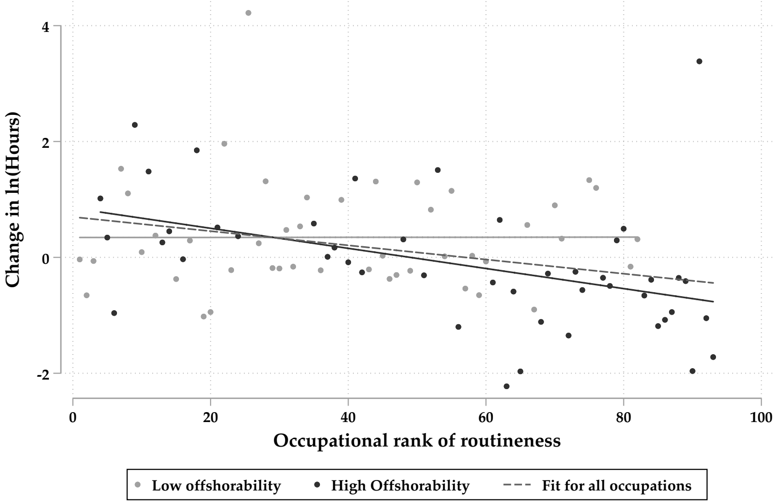
Motivation

- Concerns about the effects of new technologies on labour demand:
  - Routine-Biased Technological Change / Automation
  - Offshoring (works just like a “new technology”)
- BUT “it is harder than one might think to write down economic models in which workers as a group are harmed by new technology” (Caselli and Manning, 2019)
  - Threats to employment through impact on the competitiveness of markets in the presence of frictions rather than from changes in the production function in the presence of frictionless markets.

The Impact of Routineness & Offshorability on Labour Hours



Recent Survey Evidence

- Increasing talent shortage with only 40% of the firms report that it is a skill issue, while 60% of them stress lack of experience or human strengths.

> *" Most of the top ten in-demand roles today require post-secondary training and not always a full university degree.[...] In the digital age, employment will not always require a college degree, but will rely heavily on continual skills development as even the most traditional roles are augmented with new technology."*
>
> *(Manpower Group, 2018, p.6)*

- Machine-specific experience ranging from the knowledge of production procedures to the ability to understand blueprints, schematics and manuals.
- Many other types of machines, each with its own specific blueprints, schematics and manuals.
- Retraining to a new machine can be costly, making firms and workers cautious about potential mismatch.

Our Approach

- Challenges to the rosy neoclassical view come from ...

  ... Structural Story

  - Structural demand shift for certain skills (RBTC vs. SBTC).
  - Vertical skill-task mismatch.
  - Growing empirical and theoretical evidence.

  ... Frictional Story

  - Search frictions hinder the efficient matching between heterogeneous firms and workers.
  - Horizontal skill-task mismatch.
  - TC increases productivity of ideal match relative to less-than-ideal ones, above and beyond any considerations of skill or routine bias.

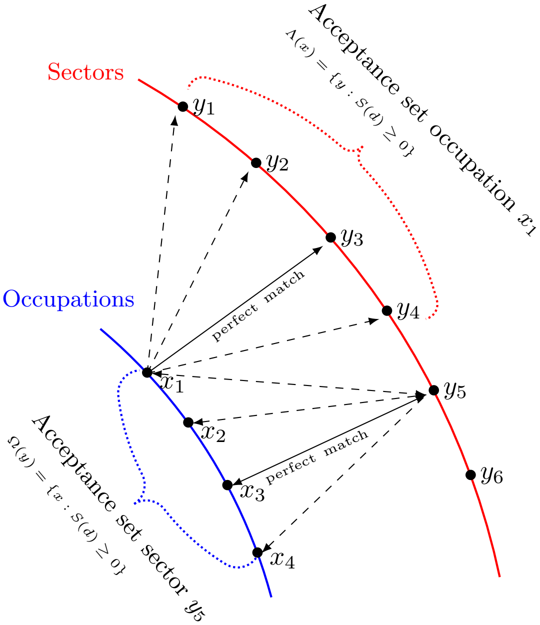
  ⇒ Core-Biased Technological Change

  - Additional effects of automation and offshoring that are at work independently from any vertical heterogeneity.

Model — Skills and Tasks

- Firms that need heterogeneous tasks to be performed and workers endowed with heterogeneous skills to perform those tasks.
- Heterogeneity as horizontal differentiation with workers and firms having different "addresses" along the unit circle.
  - ⇒ Circular Sorting Model
  - Continuum of workers with heterogeneous occupation-specific core-skill x and continuum of firms with heterogeneous sector-specifc core-tasks y.
  - ⇒ Core-biased Technological Change.
  - ⇒ Complementarity induces sorting!
- Search frictions hamper the formation of ideal matches.
  - ⇒ Mismatch between skills and tasks

$$d(x, y) = \min\left[x - y + 1, y - x\right]$$


Sectors
Occupations
Acceptance set occupation x_1
$\Lambda(x) = \{y : S(d) \geq 0\}$
Acceptance set sector y_5
$\Omega(y) = \{x : S(d) \geq 0\}$
perfect match
perfect match
y_1
y_2
y_3
y_4
y_5
y_6
x_1
x_2
x_3
x_4

Model — Search & Matching

- Standard DMP setup with CRS matching function and Nash Bargaining
- Workers of type x accept a job of type y if and only if

$$\Lambda(x) = \{y : S(x, y) \geq 0\} \quad \& \quad \Phi(y) = \{x : S(x, y) \geq 0\}$$

$$\Rightarrow \quad M(x, y) = \{x, y : S(x, y) \geq 0\} .$$

- Appealing feature of uniformly distributed skills & tasks:
  - → Identical values of unemployment & vacancies.
  - → Values of employment, production and wages only depend on mismatch d.
  - → Acceptance sets endogenously determined by common maximum distance d^* from own address.

$$\Lambda(x) = [y - d^*, y + d^*] \quad \& \quad \Phi(y) = [x - d^*, x + d^*] \qquad (1)$$

for all x and y.

Model — Production, Automation & Offshoring I

- Match Surplus:

$$s(d) = f(d) - \rho K(d) = \Phi A^{\frac{1}{1-\beta}} L(d) \tag{2}$$

- $A > 0$ is total factor productivity, which we will simply call automation henceforth.
- Efficiency units of domestic worker depends on subtasks performed.
  → Each task d consists of continuum of subtasks indexed $i \in [0, 1]$ in increasing order of ability to perform tasks:

$$L(d, i) = Fi - \frac{\gamma A}{2} d. \tag{3}$$

- Some subtasks Ω are offshored.
  - Subtasks $i \in (\Omega, 1]$ are assigned to the domestic worker whereas subtasks $i \in [0, \Omega)$ are offshored:

$$L(d) = \int_{\Omega}^{1} L(d, i)\, di = \frac{1}{2}(1 - \Omega)\left[F(1 + \Omega) - \gamma A d\right]. \tag{4}$$

Model — Production, Automation & Offshoring II

- Match surplus for mismatch d can be finally expressed as:

$$s(d) = \frac{\Phi}{2} A^{\frac{1}{1-\beta}} (1-\Omega) \left[F(1+\Omega) - \gamma A d\right] \tag{5}$$

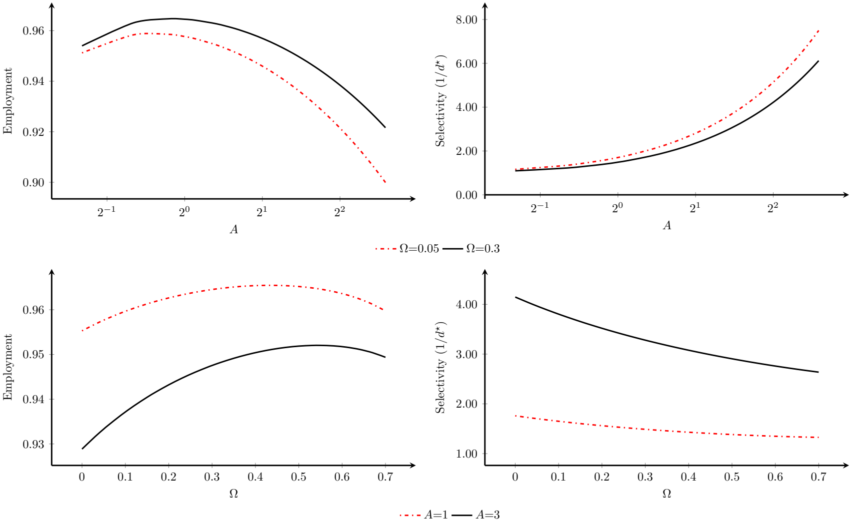
  for $d \in [0, F(1+\Omega)/\gamma A]$ and zero otherwise.

- The balance of 4 effects determines the effect of automation and offshoring:

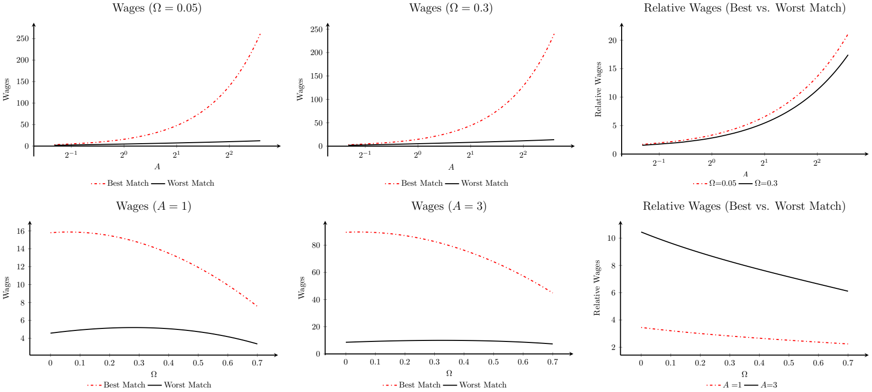
$$\frac{ds(d)}{dA} = \underbrace{\frac{\Phi}{2} \frac{1}{1-\beta} A^{\frac{\beta}{1-\beta}} (1-\Omega) \left[F(1+\Omega) - \gamma A d\right]}_{\text{productivity effect}} - \underbrace{\frac{\Phi}{2} A^{\frac{1}{1-\beta}} (1-\Omega) \gamma d}_{\text{mismatch effect}},$$

$$\frac{ds(d)}{d\Omega} = \underbrace{\frac{\Phi}{2} A^{\frac{1}{1-\beta}} (1-\Omega) F}_{\text{specialization effect}} - \underbrace{\frac{\Phi}{2} A^{\frac{1}{1-\beta}} \left[F(1+\Omega) - \gamma A d\right]}_{\text{substitution effect}}.$$

Simulation — Employment & Selectivity



Simulation — Wages



Data

- We capture skill heterogeneity at the occupational level and task heterogeneity at the sectoral level.
- Data on employment and mismatch from EULFS for country × industry × occupation × year
  - 16 sectors (out of 21 in the NACE Rev.2 classification; dropped public and agricultural sectors).
  - 92 occupations (out of 28 in the ISCO-88 classification; dropped occupations closely associated to public and agricultural sectors).
  - Years: 1995-2010.
  - 13 Countries with full coverage (Austria, Belgium, Germany, Denmark, Spain, France, Great Britain, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal).
- Offshorability from Blinder and Krueger (2013)
- Routine Task Intensity (RTI) from Autor and Acemoglu (2011)

Measuring Specialization

- Sectors to proxy "tasks" and occupations to proxy "skills".
- Define selectivity as the concentration of an occupation's employment across sectors

  ⇒ Sectoral Specialization of the Occupation **(SSO)**.
- Herfindahl Index of occupation's employment share across industries.

$$SSO_{oi} = \sum_{k \in \mathcal{K}} \left(\frac{L_{oki}}{\sum_{k \in \mathcal{K}} L_{oki}} \right)^2, \tag{6}$$

  ⇒ High SSO: few sectors account for a large share of the occupation's employment.

  ⇒ Low SSO: Workers in occupation are equally distributed across sectors.

  ⇒ Inversely related to size of the theoretical matching set.

Empirical Strategy

Step 1: From Technology to Selectivity

$$\Delta ln(SSO_{oi}) = \beta_1 RTI_o \times I^H_{oi} + \beta_2 RTI_o \times I^L_{oi} + \beta_3 Offshor_o + Z'_{oi}\mathbf{C} + \mu_i + \epsilon_{oi} \tag{7}$$

Step 2: From Selectivity to Employment

$$\Delta ln(Hours_{oi}) = \gamma + \delta_1 \Delta ln(SSO_{oi}) + K'\mathbf{C_2} + \eta_i + \upsilon_{oi} \tag{8}$$

- The model has two main implications:
  1. $\beta_1 > 0$

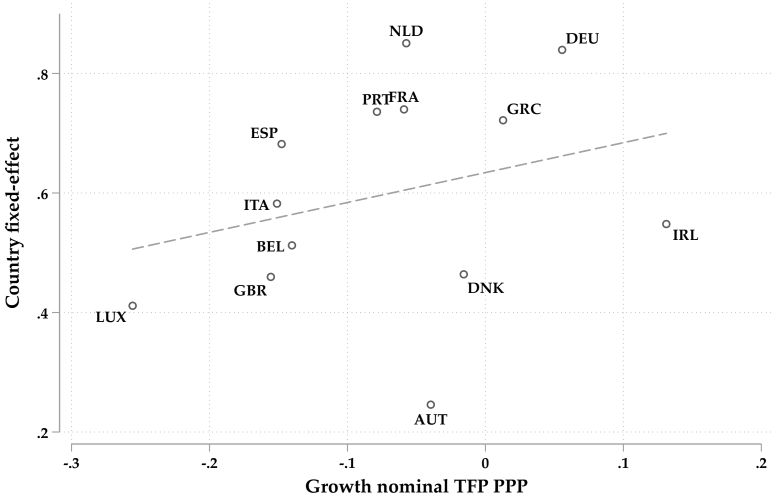
     $\Rightarrow$ Automation and offshoring fosters selectivity from 1995 to 2010.
  2. $\delta_1 < 0$

     $\Rightarrow$ Increased selectivity decreases employment.

Table 1: Selectivity, Automation & Offshoring

	Dep. Var.: $\Delta ln(SSO)$				
	(1)	(2)	(3)	(4)	(5)
RTI	0.0755			0.0312	
	(0.0522)			(0.0552)	
$RTI \times I^H$		0.207**	0.168*		0.301**
		(0.100)	(0.0994)		(0.150)
$RTI \times I^L$		-0.0151	0.00885		0.00952
		(0.0792)	(0.0781)		(0.0972)
Offshor.	-0.0765*	-0.0923**	-0.123**	-0.0691	-0.0943**
	(0.0414)	(0.0432)	(0.0525)	(0.0427)	(0.0440)
$RTI \times$ *Offshor.*			0.0667		
			(0.0470)		
$Share^{95}$				0.0727	
				(2.117)	
$Share^{95} \times RTI$				4.874***	
				(1.596)	
SSO^{95}	-1.146***	-1.231***	-1.328***	-1.156***	-1.268***
	(0.184)	(0.189)	(0.203)	(0.183)	(0.195)
Observations	1,063	1,063	1,063	1,063	1,063
R-squared	0.139	0.143	0.149	0.146	0.115
Fixed effects	Country	Country	Country	Country	Country
Spillover Controls					Yes

Country fixed effects and TFP change.



Selectivity & Employment

$$\Delta ln(Hours_{oi}) = \gamma + \underbrace{\delta_1 \Delta ln(SSO_{oi})}_{\substack{\text{Enodgeneity/Rev. Causlity} \\ \Rightarrow\textbf{Double-Bartik Instrument}}} + K'\mathbf{C_2} + \eta_i + \upsilon_{oi} \tag{9}$$

- Construction of Double-Bartik Instrument:
  1. Bartik-predicted employment change

$$\widehat{L^b_{oik,2010}} = g^b_{o,-i,k,2010} \times s_{o,i,k,1995} \tag{10}$$

$\Rightarrow$ Occupation $\times$ Industry grows at same rate as all other countries.

  2. Bartik-predicted selectivity using the shares computed in the first step to derive the Herfindahl index

$$\widehat{SSO^b_{oi,2010}} = \sum_{k \in \mathcal{K}} (\hat{s}^b_{oik,2010})^2$$

  3. Construct instrument as:

$$\Delta \widehat{ln(SSO^b_{oi})} = ln\left(\frac{\widehat{SSO^b_{oi,2010}}}{SSO_{oi,1995}}\right)$$

Table 2: Selectivity & Employment

	Dep. Var.: $\Delta ln(Hours)$				
	(1)	(2)	(3)	(4)	(5)
$\Delta ln(SSO)$	-0.160***	-0.161*	-0.169***	-0.267***	-0.446***
	(0.0417)	(0.0852)	(0.0349)	(0.0658)	(0.0809)
$\Delta ln(L^b)$	0.266***	0.266***	0.297***	0.302***	0.0697
	(0.0640)	(0.0647)	(0.0629)	(0.0650)	(0.0883)
RTI			-0.226***	-0.225***	
			(0.0425)	(0.0427)	
Offshor.			0.0719	0.0668	
			(0.0562)	(0.0578)	
$RTI \times$ *Offshor.*			-0.178***	-0.181***	
			(0.0447)	(0.0453)	
First Stage		1.780***		1.789***	1.925***
		(0.127)		(0.139)	(0.204)
FE	Country	Country	Country	Country	Country × Occup.
Instrument	No	Bartik	No	Bartik	Bartik
Observations	1,073	1,073	1,062	1,062	1,073
K-P F-Test 1st		196.6		165.1	88.71

Table 3: Selectivity & Employment II

	Dep. Var.: $\Delta ln(Hours)$					
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta ln(SSO)$	-0.339***	-0.694***				
	(0.101)	(0.151)				
$\Delta ln(SSO) \times I^H$			-0.343***	-0.507***	-0.357***	-0.714**
			(0.119)	(0.159)	(0.126)	(0.288)
$\Delta ln(SSO) \times I^L$			0.105	0.0594	0.244**	0.241**
			(0.107)	(0.112)	(0.0973)	(0.109)
$\Delta ln(L^b)$	0.223***	-0.145	0.326***	0.248***	0.113	-0.0954
	(0.0845)	(0.109)	(0.0700)	(0.0764)	(0.0846)	(0.116)
RTI	-0.194***					
	(0.0511)					
Offshor.	0.0445		0.00564	0.0340		
	(0.0644)		(0.0521)	(0.0606)		
$RTI \times$ *Offshor.*	-0.182***		-0.205***	-0.147***		
	(0.0507)		(0.0394)	(0.0485)		
FE		Occup.			Occup.	Occup.
Instrument	Bartik	Bartik	Bartik	Bartik	Bartik	Bartik
$\Delta ln(SSO) > 0$	Yes	Yes		Yes		Yes
Observations	558	563	1,062	558	1,073	563
K-P F-Test 1st	90.11	63.88	24.31	17.93	9.593	11

Conclusion

- Better matches enjoy a comparative advantage in exploiting automation and a comparative disadvantage in exploiting offshoring.
  - Automation as an increase in the productivity (productivity effect), but also increase in the productivity of ideal matches relative to less-than-ideal ones (mismatch effect)
  - Offshoring as an increase in the productivity of any given match due to subtask specialization (specialization effect), but also as a decrease in assigned subtasks (substitution effect).
    - ⇒ Core-Biased Technological Change: Substitutability between less-than-ideal skills and ideal ones (core competencies).
- Negative relation of employment and wage equality with improvements in technology arises naturally in our setting of horizontal mismatch.
- Core-biased change illustrates a more general idea of how wages and jobs in frictional labour markets may react to other shocks.

Thank You!

DMP Setup

- Workers/Firms are infinetly lived, risk-neutral, discount rate ρ
- Search is random with matching function:

$$M(U, V) = \theta U^{\varphi} V^{1-\varphi}$$

- Productive matches fall in the acceptance ranges for y and x $\Rightarrow$ Symmetry implies one $d*$

$$V_E(d) = w(d) - \delta\,(V_E(d) - V_U)$$

$$V_U = 2 * q_u(\theta) \int_0^{d^\star} (V_E(z) - V_U)\, dz$$

$$V_P(d) = f(d) - w(d) - c) - \delta * (V_P(d) - V_V) > V_P(d^*) = 0$$

$$V_V = -c + 2 * q_v(\theta) \int_0^{d^\star} (V_P(z) - V_V) \stackrel{!}{=} 0$$

- Nash Bargaining, free-entry and steady-state flow condition close the model.

Core-Biased Technological Change

- What is the contribution of CBTC to the total effect of automation on employment?
  1. Automation $\rightarrow$ Selectivity:

$$\Delta^{\text{RTI on SSO}} = \hat{\beta}_1 RTI_{oi} \times I_{oi}^H$$

  2. Selectivity $\rightarrow$ Employment:

$$\hat{\delta}_1 \Delta ln(SSO_{oi})$$

  3. Total Effect:

$$\Delta^{tot} = \underbrace{\widehat{\zeta}_1 RTI_{oi}}_{-0.443^{***}} \times I_{oi}^H$$

  4. Relative effect:

$$\frac{\Delta^{\text{RTI-based SSO}}}{\Delta^{tot}} = \frac{\hat{\delta}_1 \times \hat{\beta}_1 \left(RTI_o \times I_{oi}^H\right)}{\hat{\zeta}_1 RTI \times I_{oi}^H} = \frac{\hat{\delta}_1 \times \hat{\beta}_1}{\hat{\zeta}_1} = \frac{0.207 \times (-0.343)}{(-0.445)} = 0.160$$

Other Measures of Mismatch

- Educational mismatch = over-education + under-education:
  - Compare each worker's education in terms of years to the educational level of his peers at the date of the observation.
  - A worker is over-educated (under- educated) if her educational level is above (below) the average in her occupation, industry, country and 10-year cohort by more than 2 standard deviations.
- Unemployment duration
  - We assign an unemployed worker to the cell of his last job and aggregate the observations at the 2-digit ISCO level.

Table 4: Impact of Technology on Educational Mismatch & Unemployment Duration

	ΔUnemployment Duration	ΔMismatch	ΔUnder Education	ΔOver Education
	(1)	(2)	(3)	(4)
RTI	0.0409*	-0.0347	-0.00340***	0.00305***
	(0.0243)	(0.0984)	(0.000742)	(0.000778)
Offshor.	-0.0183	0.0532	0.00220**	-0.00167**
	(0.0319)	(0.114)	(0.000858)	(0.000795)
RTI × *Offshor.*	0.0454	-0.290***	-0.00177**	-0.00113
	(0.0328)	(0.111)	(0.000814)	(0.000805)
Observations	905	1,915	1,915	1,915
R-squared	0.183	0.236	0.143	0.235
Fixed effects	Country-Industry			

Spillover & Aggregate Effects

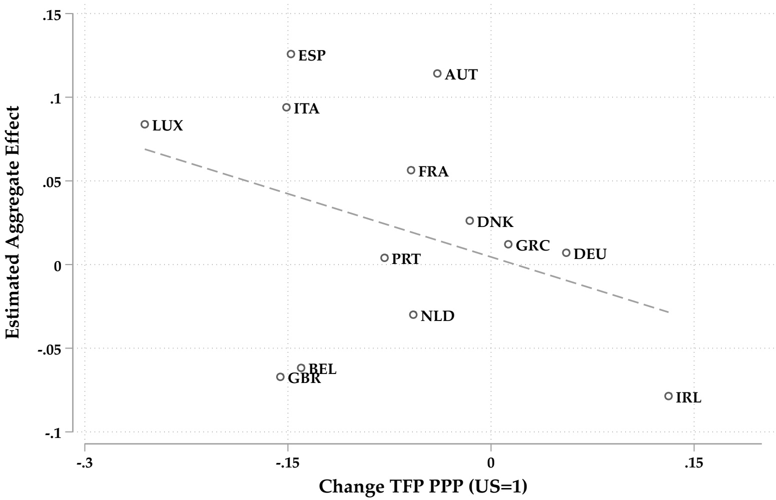
- Consider two countries, each with two occupations and workers mobile only between occupations within a country:
  1. In one of the countries an occupation is automated and some jobs in that occupation vanish
     - ⇒ Shock in one occupation has spillover effects on the other occupation; strength of the spillover effects depend on the share of treated occupations
  2. Now instead all occupations in one country (i.e. in half of the countries) are affected:
     - ⇒ Fraction of treated occupations is 1 in the affected country and 0 in the other; spillovers are immaterial for general equilibrium effects.
- Following Berg and Streitz (2019), estimate

$$\Delta ln(Hours)_{oi} = \beta_0 + \beta_1 I_o^H + \beta_T \overline{RTI}_{-oi} I_o^H + \beta_C \overline{RTI}_{-oi} I_o^L + \epsilon_{oi}.$$

- where β_T and β_C inform about spillovers and we can aggregate

$$E\left[\overline{\Delta ln(Hours)}_i | \overline{RTI}_i\right] = \beta_0 + (\beta_1 + \beta_C)\overline{RTI}_i + (\beta_T - \beta_C)\overline{RTI}_i^2,$$

Estimated Aggregate Effects & TFP



Vertical Specialization