North-South Trade: The Impact of Robotization

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Andreas Baur [1,2] Lisandra Flach [1,2,4,5] Isabella Gourevich[1,2] Florian Unger[3,4]

[1]ifo Institute [2]LMU Munich [3]University of Göttingen [4]CESifo [5]CEPR

Introduction

- **Automation**, which takes place predominantly in advanced economies, has caused debate on potentially **disruptive effects** in domestic markets

  Graetz and Michaels (2018), Dauth et al. (2021), Acemoglu et al. (2020)

- Nevertheless, automation also **impacts trading partners** in a globalized and interconnected world

- **Reorganization of global value chains?** Formerly labor intensive production in Global South might be reshored to Global North

Channels

Two potential effects of automation in Northern countries onto North-South trade:

1. Shift in **relative production costs** reduces comparative advantage of Southern countries in (labor-intensive) manufacturing → reduces demand for imports from the South

   Kugler et al. (2020), Faber (2020), Krenz et al. (2021)

Channels

Two potential effects of automation in Northern countries onto North-South trade:

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   Kugler et al. (2020), Faber (2020), Krenz et al. (2021)

2. Firms in the North **improve efficiency** $\rightarrow$ increases demand for intermediate inputs from the South

   Artuc et al. (2020), Stapleton and Webb (2020), Cilekoglu et al. (2021)

This Project

Research question:

What is the effect of robotization in the global North on firm-level exports from Latin America?

What we do

1. Develop theoretical model yielding different predictions on **within-industry** and **between-industry** trade effects of robotization
2. Novel combination of data sources: firm-level customs data (firm-product-destination-year), robotization in destination (sector-destination-year) and **value chain linkages**
3. Estimate **effect of shock on southern firms** in different industries across destination countries and along the value chain

Preview of Results

- Theoretical model predicts negative **within-industry** and positive **between-industry** effects on trade flows from South to North
- Empirically, **negative** effect on trade flows of robotization in the **same industry**
- Accounting for shocks along the entire **value chain reverses** the effect

→ Important to account for **value chain linkages** when evaluating exposure of southern firms to robotization shocks

Outline

- Theoretical Model
- Data and Stylized Facts
- Empirical Analysis

Theoretical Model

Model Setup

- Setup is based on Antràs & Helpman (2004, 2007)
- Two countries *North* and *South* with $w^N > w^S$ and multiple sectors
- Heterogeneous final-goods firms in the North require two intermediate inputs:

1. $m_j(i)$ from same industry j: Production with **vertical integration** in North w^N or **sourcing** from South at $w^S\tau < w^N$; with fixed costs $f_O^S > f_V^N$
2. $m_k(i)$ from other industry $k \neq j$: Always sourced from the South

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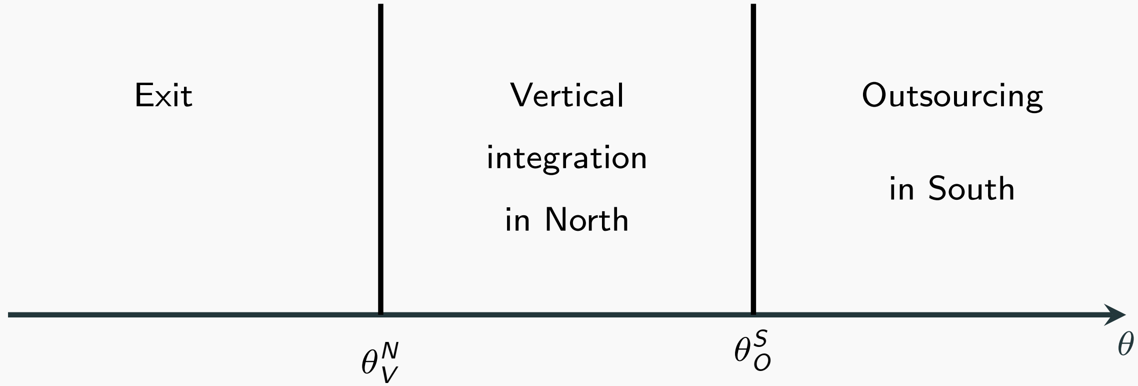
  2. $m_k(i)$ from other industry $k \neq j$: Always sourced from the South

$\longrightarrow$ Decision on sourcing of same industry input m_j depends on firm productivity θ



Automation Shock and Trade Effect

- We introduce an endogenous automation choice
- Industry-specific shock $\rightarrow$ positive automation shock reduces cost of automation
- Automation shock reduces profitability of sourcing from the S relative to N

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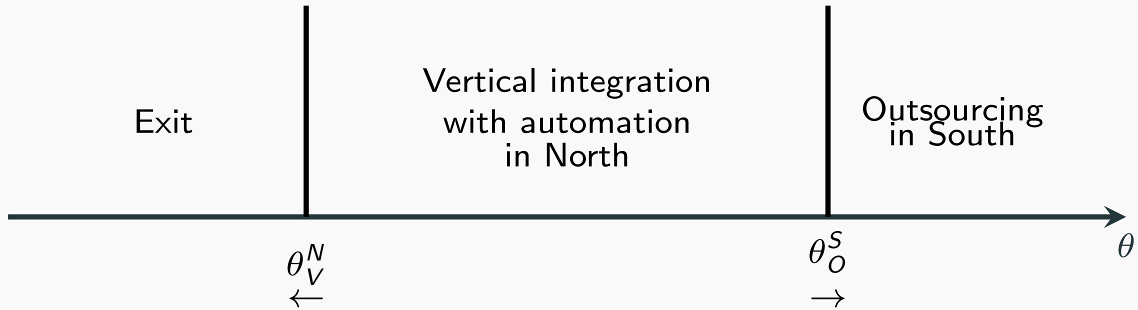
Prediction 1: A reduction in automation costs in industry j reduces trade flows from South to North within industry j



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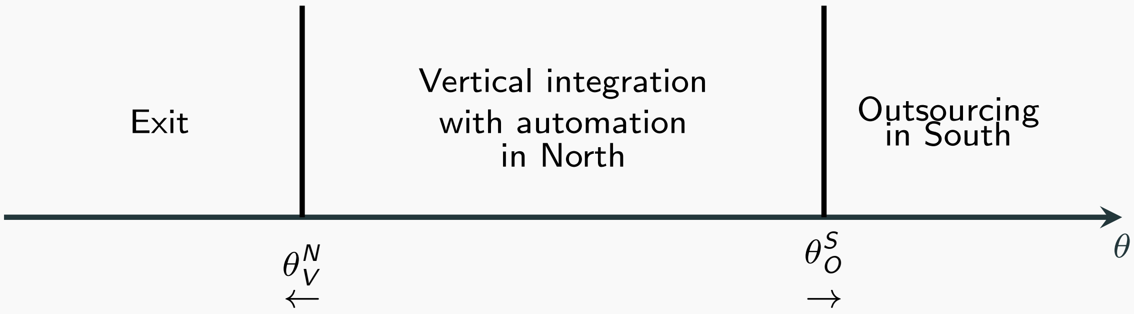

Prediction 2: A reduction in automation costs in industry j increases trade flows of between-industry inputs k from South to North

- Firms with $\theta_V^N \leq \theta < \theta_O^S$ demand more **between-industry inputs** $m_k(i)$
- Additionally, a higher share of active firms produces under vertical integration and benefits from automation

Data and Stylized Facts

Data Sources

Firm-Level Exports

- Sources: World Bank Export Dynamics Database & SECEX
- Coverage: Brazil, Mexico, Peru and Uruguay for 2000 - 2007
- Universe of firm-level exports by HS6 product, destination country and year

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Robotization

- Source: International Federation of Robotics - IFR
- Coverage: 75 countries (we focus on OECD countries)
- Robots stock in 14 broad industry sectors

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Input-Output Tables

- Source: Bureau of Economic Analysis (US for the year 1997)
- Coverage: Trace technology-based input-output-flows across 341 industries

Export Shares

Table 1: Export Shares *(in %)* in 2001

	BRA	MEX	PER	URY
A: By Destination Region				
OECD	66.75	96.22	76.64	42.17
Rest Latin America	17.13	3.77	11.95	44.50
RoW	16.12	1.01	11.41	13.33
B: By Sector Group				
Agriculture & Mining	18.17	10.99	20.75	14.07
High Manufacturing	25.54	60.65	0.74	0.93
Other Manufacturing	56.29	28.35	78.50	85.00
Total Observations	236,451	202,646	40,985	8,731

Empirical Analysis

Empirical Strategy

Same Industry Mapping

$$X^{o}_{fpdt} = \exp\left[\zeta_{fpd} + \delta_{pt} + \pi_{sot} + \gamma_{odt} + \beta_1 asinh(robots_{sdt}) + \beta_2 \ln imp_{pdt}\right] \times \epsilon_{fpdt}$$

where f - firm in country of origin, p - product, s - sector, d - destination country, o - origin country, t - year

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Value Chain Linkage Mapping

$$X^o_{fpdt} = \exp\left[\zeta_{fpd} + \delta_{pt} + \pi_{sot} + \nu_{sdt} + \gamma_{odt} + \beta_1 asinh(robots^{IO}_{pdt}) + \beta_2 \ln imp_{pdt}\right] \times \epsilon_{fpdt}$$

Robots shock: $robots^{IO}_{pdt} = \sum_s \omega_{ps}\ robots_{sdt},$

- $\omega_{ps} \in [0, 1]$ are allocation coefficients: the share products p's total sales which are used as inputs in the production of sector s

In the preferred specification robots stock is weighted by industry's value-added and the estimator is Poisson Pseudo Maximum Likelihood

Baseline Effect

Table 2: PPML Baseline Results: Same industry vs. value chain linkages

	Same industry linkages	
Dependent Var: X_{fpdt}	(1)	(2)
$asinh(robots)_{sdt}$	-0.162***	-0.165***
	(0.0503)	(0.0478)
$asinh(robots^{IO})_{pdt}$		
Total Imp of Dest_{pdt}	0.794***	0.825***
	(0.105)	(0.109)
Number of Observations	93,886	93,884
FPD FE	Yes	Yes
ODT FE	Yes	Yes
PT FE	Yes	Yes
SOT FE		Yes
SDT FE		

Note: Robust standard errors clustered by SD in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Baseline Effect

Table 2: PPML Baseline Results: Same industry vs. value chain linkages

Dependent Var: X_{fpdt}	Same industry linkages (1)	(2)	Value chain linkages (3)	(4)	(5)	(6)
$asinh(robots)_{sdt}$	-0.162***	-0.165***				
	(0.0503)	(0.0478)				
$asinh(robots^{IO})_{pdt}$			0.360***	0.201***	0.481***	0.297***
			(0.119)	(0.0500)	(0.150)	(0.0446)
Total Imp of $Dest_{pdt}$	0.794***	0.825***	0.851***	0.852***	0.930***	0.911***
	(0.105)	(0.109)	(0.110)	(0.112)	(0.124)	(0.123)
Number of Observations	93,886	93,884	87,916	87,914	87,848	87,846
FPD FE	Yes	Yes	Yes	Yes	Yes	Yes
ODT FE	Yes	Yes	Yes	Yes	Yes	Yes
PT FE	Yes	Yes	Yes	Yes	Yes	Yes
SOT FE		Yes		Yes		Yes
SDT FE					Yes	Yes

Note: Robust standard errors clustered by SD in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

$\longrightarrow$ **Taking value chain linkages into account is crucial**

Robustness Checks

Results remain robust when:

- Accounting for market **entry and exit** Regression Results
- Controlling for **firm level robot adoption** over time Regression Results
- Using **OLS** regression Regression Results

Conclusion

- We evaluate the effects of robot adoption in OECD countries on exports from Latin America to the OECD along the value chain
- Novel combination of firm-level data with data on robot adoption and input-output linkages
- Exports in the same industry decrease but increase along the value chain
- Theoretical model explains negative within-industry and positive between-industry effects on trade flows from South to North
- Important to account for supply chain linkages when drawing policy conclusions

Thank you for your attention

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Scope for Quality Upgrading

Table 3: Effect on South to North Trade depending on the Scope for Quality Differentiation

	Same industry linkages		Value chain linkages			
Dependent Var: X_{fpdt}	(1)	(2)	(3)	(4)	(5)	(6)
$asinh(robots)_{sdt}$	0.0957	0.0731				
	(0.0816)	(0.0860)				
$asinh(robots^{IO})_{pdt}$			0.132	0.123	0.172	0.164
			(0.119)	(0.122)	(0.108)	(0.116)
$\times$ Ladder_{pdt}	-0.145***	-0.132***	0.0961*	0.107*	0.0997*	0.111*
	(0.0310)	(0.0321)	(0.0513)	(0.0606)	(0.0530)	(0.0644)
Total Imp of Dest_{pdt}	1.061***	1.065***	1.067***	1.082***	1.146***	1.165***
	(0.142)	(0.143)	(0.148)	(0.151)	(0.145)	(0.145)
Number of Observations	58,776	58,772	56,366	56,362	56,294	56,290
FPD FE	Yes	Yes	Yes	Yes	Yes	Yes
ODT FE	Yes	Yes	Yes	Yes	Yes	Yes
PT FE	Yes	Yes	Yes	Yes	Yes	Yes
SOT FE		Yes		Yes		Yes
SDT FE					Yes	Yes

Note: Robust standard errors clustered by SD in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Quality ladder measure is taken from Khandelwal (2010). A quality ladder is assigned to each product and represents the vertical differentiation possibility of a product. A higher ladder indicates a large scope for quality differentiation.

Table 4: PPML Baseline w/ Control for Market Entry and Exit & Firm Level Robot Adoption

	Same industry linkages		Value chain linkages			
Dependent Var: X_{fpdt}	(1)	(2)	(3)	(4)	(5)	(6)
$asinh(robots)_{sdt}$	-0.269**	-0.269**				
	(0.112)	(0.113)				
$asinh(robots^{IO})_{pdt}$			0.207***	0.209***	0.222***	0.226***
			(0.0732)	(0.0733)	(0.0590)	(0.0577)
Total Imp of Dest_{pdt}	1.046***	1.050***	1.100***	1.102***	1.141***	1.147***
	(0.0983)	(0.0988)	(0.0938)	(0.0950)	(0.101)	(0.103)
Number of Observations	657,152	656,980	602,262	602,168	601,994	601,942
FPD FE	Yes	Yes	Yes	Yes	Yes	Yes
FT FE	Yes	Yes	Yes	Yes	Yes	Yes
ODT FE	Yes	Yes	Yes	Yes	Yes	Yes
PT FE	Yes	Yes	Yes	Yes	Yes	Yes
SOT FE		Yes		Yes		Yes
SDT FE					Yes	Yes

Note: Robust standard errors clustered by SD in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Robustness Checks

Table 5: PPML Baseline w/ Control for Market Entry and Exit

	Same industry linkages		Value chain linkages			
Dependent Var: X_{fpdt}	(1)	(2)	(3)	(4)	(5)	(6)
$asinh(robots)_{sdt}$	-0.143	-0.153*				
	(0.0899)	(0.0863)				
$asinh(robots^{IO})_{pdt}$			0.167***	0.153**	0.156**	0.144*
			(0.0619)	(0.0660)	(0.0744)	(0.0818)
Total Imp of Dest$_{pdt}$	0.859***	0.879***	0.896***	0.909***	0.961***	0.965***
	(0.101)	(0.103)	(0.0971)	(0.0999)	(0.111)	(0.112)
Number of Observations	1,485,012	1,485,012	1,380,924	1,380,922	1,380,914	1,380,908
FPD FE	Yes	Yes	Yes	Yes	Yes	Yes
ODT FE	Yes	Yes	Yes	Yes	Yes	Yes
PT FE	Yes	Yes	Yes	Yes	Yes	Yes
SOT FE		Yes		Yes		Yes
SDT FE					Yes	Yes

Note: Robust standard errors clustered by SD in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Robustness Checks

Table 6: Robustness with linear regression - Baseline: Same industry vs. value chain linkages

	Same industry linkages		Value chain linkages			
Dependent Var: X_{fpdt}	(1)	(2)	(3)	(4)	(5)	(6)
$asinh(robots)_{sdt}$	-0.0690	-0.0891**				
	(0.0423)	(0.0422)				
$asinh(robots^{IO})_{pdt}$			0.0340	0.0578***	0.0375	0.0565**
			(0.0248)	(0.0214)	(0.0291)	(0.0252)
Total Imp of Dest_{pdt}	0.323***	0.333***	0.346***	0.356***	0.344***	0.348***
	(0.0382)	(0.0378)	(0.0408)	(0.0403)	(0.0359)	(0.0357)
Number of Observations	93,886	93,884	87,916	87,914	87,848	87,846
FPD FE	Yes	Yes	Yes	Yes	Yes	Yes
ODT FE	Yes	Yes	Yes	Yes	Yes	Yes
PT FE	Yes	Yes	Yes	Yes	Yes	Yes
SOT FE		Yes		Yes		Yes
SDT FE					Yes	Yes

Note: Robust standard errors clustered by SD in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

North-South Model of International Trade

Model setup

- Two countries: North and South
- Heterogeneous final-good firms located in North
- Sourcing of inputs from South or vertical integration in North
- Production of inputs with one unit of labor per unit of output
- Perfectly elastic supply of labor in both regions with wages $w^N > w^S$

Preferences

- Inverse demand function for one differentiated variety i in sector j:

$$p_j(i) = X_j^{\mu-\alpha} x_j(i)^{\alpha-1}, \;\; 0 < \alpha < 1$$

- $\alpha > \mu$: substitutability of varieties higher within sector than across sectors

Production and Sourcing Decision

- Final-good producer with productivity θ located in the North uses two variety-specific inputs:

$$x_j(i) = \theta \left(\frac{m_j(i)}{\eta_j}\right)^{\eta_j} \left(\frac{m_k(i)}{1-\eta_j}\right)^{1-\eta_j}, \quad 0 < \eta_j < 1,$$

- Intermediate input $m_j(i)$ from same industry j:
  - Production with **vertical integration** in North at wage w^N
  - or **sourcing** from South at $w^S\tau$, with trade costs $\tau > 0$
  - Marginal cost of sourcing lower than under vertical integration (without automation): $w^N > w^S\tau$
  - Fixed cost of sourcing larger than for vertical integration: $f_O^S > f_V^N$
- Intermediate input $m_k(i)$ from other industry $k \neq j$:
  - Production only in South at wage w^S
  - Always **sourcing**

Automation Choice with Vertical Integration

- Automation of production under vertical integration in North
  - **reduces** marginal cost of **within-industry inputs**: $\frac{w^N}{a_j(i)}$,
  - leads to **additional innovation costs** per unit of input: $\frac{\kappa_j}{\xi_j} a_j (i)^{\xi_j}$
- Cost minimization leads to optimal automation choice:

$$a_j = \left(\frac{w^N}{\kappa_j} \right)^{\frac{1}{1+\xi_j}},$$

  - increasing in Northern wage rate w^N,
  - decreasing in automation cost parameters κ_j, $\xi_j > 0$
- We consider an **industry-specific automation shock**:

  reduction in cost parameter $\kappa_j \Rightarrow$ increase in automation a_j

Effect of Automation on Sourcing Decision (1)

- Reduction in marginal cost of production (lower κ_j) with vertical integration:

$$c^N_{j,V} \equiv \left[\frac{\xi_j + 1}{\xi_j} \left(w^N\right)^{\frac{\xi_j}{1+\xi_j}} \kappa_j^{\frac{1}{1+\xi_j}} \right]^{\eta_j} \left(w^S\right)^{1-\eta_j}$$

- Marginal cost with sourcing of both inputs: $c^S_{j,O} \equiv w^S \tau^{\eta_j}$
- Relative cost advantage of sourcing: $\hat{w} \equiv \frac{w^N}{\tau w^S} > 1$
- But higher fixed costs of sourcing: $f^S_O > f^N_V$
- Productivity cutoff of sourcing θ^S_O determined by $\pi_j \left(\theta^S_O\right)^S_O = \pi_j \left(\theta^S_O\right)^N_V$

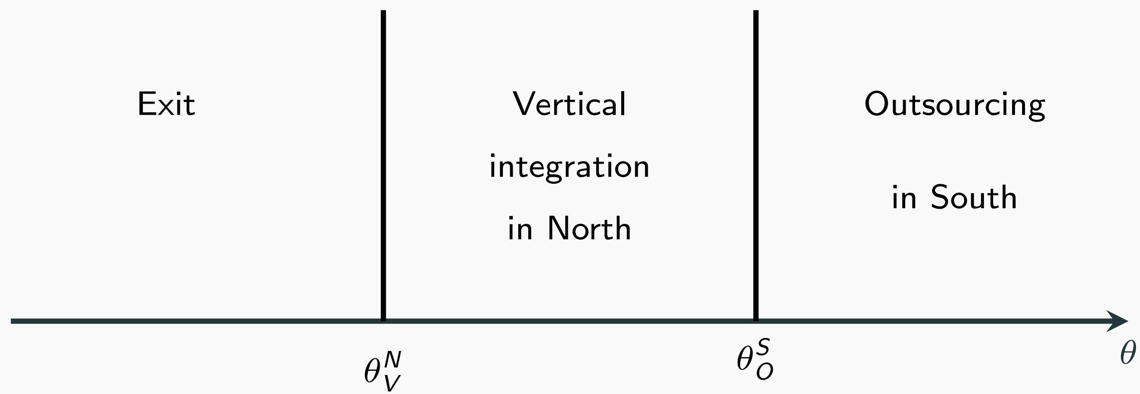
$\longrightarrow$ Automation shock reduces profitability of sourcing from South relative to vertical integration in the North

Effect of Automation on Sourcing Decision (2)

If relative fixed costs of sourcing are larger than cost advantage of sourcing (taking into account automation),

$$\frac{f_O^S}{f_V^N} > \left(\frac{\xi_j + 1}{\xi_j}\frac{\hat{w}}{a_j}\right)^{\frac{\alpha\eta_j}{1-\alpha}} \qquad \Longrightarrow \qquad \theta_O^S > \theta_V^N,$$

then only the most productive firms source within-industry inputs from South.

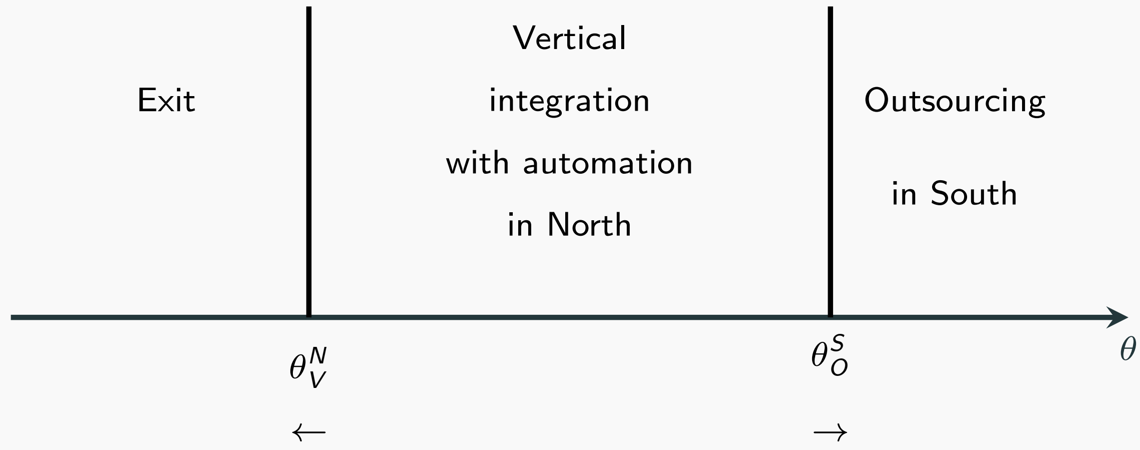


Prediction 1: Automation and Within-Industry Trade

A reduction in automation costs in industry j **reduces** trade flows from South to North **within industry** j.

- Only firms with productivity $\theta \geq \theta_O^S$ source **within-industry inputs** $m_j(\theta)$.
- With increasing automation the share of outsourcing firms declines.

$\longrightarrow$ **Within-industry trade flows** from South to North, $T_j = M_e \int_{\theta_O^S}^{\infty} \tau w^S m_j(\theta)\, g(\theta)$, decline in the degree of automation in industry j.



Prediction 2: Automation and Between-Industry Trade

A reduction in automation costs in industry j **increases** trade flows of **between-industry inputs** k from South to North.

- Automation reduces marginal cost $c_{j,V}^{N}$ under vertical integration.
- Firms with $\theta_V^N \leq \theta < \theta_O^S$ demand more **between-industry inputs** $m_k(i)$.
- Additionally, a higher share of active firms produces under vertical integration and benefits from automation.

$\longrightarrow$ **Between-industry trade flows** from South to North, $T_k = M_e \int_{\theta_V^N}^{\theta_O^S} w^S m_k(\theta)\, g(\theta)$, increase in the degree of automation in industry j.