Does Automation Adoption Drive Reshoring? A Cross-Country Investigation

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International fragmentation of production?

- The introduction of technologies such as **computers and ICTs** and the **opening of lower labor-cost countries** have contributed to an **international fragmentation of production** (Los et al., 2015; Pegoraro et al., 2020)
- However, the **increasing fragmentation of production** also exposes some **costs and risks**.
  - Loss of jobs for low-skilled workers in labor-intensive industries in developed countries to offshoring
  - External shocks are out of control for firms (2011 Tohoku Earthquake)

A debate and set of policies to **bring jobs back home (reshoring)**.

Reorganization of global production?

- The **introduction of new automation technology** may help exacerbate this trend and **bring disruption** to the existing global value chains.
  - Could **substitute workers**
  - Open up new opportunities for advanced countries to **shift from mass-production to mass-customized production** (Brettel et al., 2014)

Automation and reshoring: what do we expect?

Aggregate studies:

- Robot adoption increases reshoring (Faber, 2020; Kugler et al., 2020; Krenz et al., 2021)
- AI increases bilateral trade (Sun and Trefler, 2022)
- 3D printing technology adoption increases exports of hearing aid (Freund et al., 2022)
- Robots adoption in developed countries promote trade (Artuc et al., 2022)

Firm-level studies:

- Survey studies
  - Firms increase reshoring to home country when firms increase patenting and when home country pursues policies in promoting Industry 4.0 (Barbieri et al., 2022)
  - no relationship (Kamp and Gibaja, 2021)
- Firm-level data
  - Robot adoption firms increase their imports (Stapleton and Webb, 2020; Cilekoglu et al., 2021)

This Paper

Research Questions

- *How automation technologies affects reshoring at the macro level?*
  - How to **quantify reshoring** at the **macro level** (country and sector-country level)?
  - Does automation technologies **increase** reshoring at the macro level?
    - Is this a **linear relationship**?
    - Does this effect differ between **high-income, middle-income, lower-middle-income countries**?
    - Is there different effect for **different types of technologies?**
    - Does this effect **vary over time**?
    - Does this effect **differ between sectors: manufacturing and services?**

This Paper

Contribution

- **Offshoring and Reshoring**
  - New measure to quantify reshoring at the macro level (country and industry-country level)
    - Measure reshoring, rather than an implication of offshoring
    - Describe reshoring as a flow process
    - Take into account both intermediate inputs and final goods
    - Consider both domestic and foreign demand
    - Include many tiers, not only tier 1 in the supply chain (both direct and indirect relationships)

- **Automation and Reshoring** (Ancarani et al., 2019; Barbieri et al., 2022; Dachs et al., 2019; Faber, 2020; Stapleton and Webb, 2020)
  - Study the effects of automation adoption on reshoring and examine the different effects between countries, sectors, time and types of technologies
  - Focus on macro level (country), on both scope of technology availability (innovation) and the diffusion process (adoption)

Conceptual Framework

Our Conceptual Framework

Competition and Market size channel (Artuc et al., 2022)

- Market size channel
  - Producers substitute domestic workers for automation in automatable tasks -> lower costs of production in countries adopt automation -> an increase in demand -> an increase in imports
- Competition channel
  - Lower costs of production in countries adopt automation -> products more competitive -> producers substitute foreign products with domestic goods

Our Conceptual Framework

Productivity channel - Solow paradox?

- New technologies and productivity paradox (Solow, 1987; Acemoglu et al., 2014; Brynjolfsson et al., 2019)
- However, new technologies do have a positive impact on productivity of the sectors of adoption (Capello et al., 2022)

Our Conceptual Framework

Sunk Cost channel (Antras, 2021)

- Offshoring involves sunk cost
- Firms will not abandon their activities in other countries because of the large sunk cost in the past

Our Conceptual Framework

Characteristics and Adoption rate channel

- Current robots are only a continuous version of previous automation technologies (Fernández-Macías et al., 2021)
- Adoption is concentrated in a few firms, sectors and countries (Fernández-Macías et al., 2021; Koch et al., 2021; Benmelech and Zator, 2022)

Data and variables

Data and variables

Datasets

- **Asian Development Bank Multiregional Input-Output Tables (ADB-MRIO)**
  - Base on the World Input-Output Tables (Timmer et al., 2015)
  - Include **28 EU countries** (as of July 1, 2013), **15 other major economies**, and **19 Asian economies**
  - Cover 35 industries, at 2-digit ISIC revision 4 level
  - Cover years **2000, 2007 to 2019**

- **ADB-ADBI Innovation and Structural Transformation Database**
  - Developed by ADB Institute, ADB, and United Nations University
  - Structural change, product complexity, innovation, and global value chains **at country level**

- **Other datasets**
  - World Development Indicators
  - GeoDist from CEPII

Data and variables

Main variables:

- Reshoring (ADB-MRIO table)
- Automation adoption (ADB-ADBI Innovation and Structural Transformation Database)
- Automation innovation (ADB-ADBI Innovation and Structural Transformation Database)

Measuring Automation adoption

We use **imports** of capital goods embedding **automation** technologies

- ***Why?*** Lack of systematic firm-level info on adoption of automation/AI technologies
  - Done by several studies (Dixon et al., 2020; Bonfiglioli et al., 2020; Acemoglu et al. , 2020; Aghion et al., 2020; Domini et al., 2022)
  - Exceptions: survey data (Bessen et al., 2019; Zolas et al., 2021; Cirera et al., 2021)

- ***How?*** Identified via product codes
  - Cover six types of sub-fields related to 4IR including **CAD-CAM, Robots, Automated Welding, 3D Printing, Regulating Instruments, and ICT**
  - May cover 3IR technologies
  - At sector level

Measuring Automation innovation

We use **patents** of **automation** technologies

- ***How?***
  - PATSTAT
  - At sector level, use their measure patent content of value added where $Q_j = Pat_j / VA_j$.

New measure of reshoring

Definition

- **Reshoring** is defined as the decision to *relocate activities* back to the home country (Fratocchi et al., 2014)

Literature and Concerns about Current Measures

- **Measure through offshoring-macro data**
  - Base on imported intermediates from (Feenstra and Hanson, 1999)
    - (-) **Exclude any final goods that are assembled overseas** (Fort, 2017; Johnson, 2018)
  - Include both intermediates and final products to calculate what share of domestic demand is served by foreign products (De Backer et al., 2018)
    - (-) **Refer to only domestic demand, and exclude foreign demand**
    - (-) **Foreign input shares in value added decline may be due to a decline in production** (Krenz et al., 2021)

Literature and Concerns about Current Measures

- **Firm level data**
  - Firm-level customs data in importing and number of affiliates for each firm in the host country (Harrison and McMillan, 2011; Kovak et al., 2021; Stapleton and Webb, 2020)
    - (-) **Only available for some countries**
  - Survey data in their reshoring decision (Fort, 2017)
    - (-) **Only cover a subset of firms and only in some specific years**

Literature and Concerns about Current Measures

- **We decide to measure reshoring at macro level due to**
  - Can cover many **indirect and direct relationships** (tier 1, tier 2 or 3 in supply chain). Firm-level data is not suffificent enough to cover these relationships (except for Belgium data)
  - Can reflect **reshoring process**, including **both intermediate inputs and final goods**, consider both **domestic and foreign demand** and examine the impact on the macro level.

How we measure

- Adopt from Krenz et al., 2021
  - They only consider intermediate inputs in their measure
  - Account for only direct relationships in supply chain
- Our measure is as follows:

$$Reshoring_t = (DVA_t/FVA_t) - (DVA_{t-1}/FVA_{t-1})$$

  - DVA_t: domestic value added at time t
  - FVA_t: foreign value added at time t
  - Narrow reshoring: only domestic value added served domestic demand
  - Broad reshoring: domestic value added served both domestic and foreign demand
  - Interpretation: measures **how much domestic value added increased** relative to **foreign value added compared** to the **previous year**

How we measure

- **Matrix forms** to calculate *DVA* and *FVA*

$$\boldsymbol{S} = \boldsymbol{VLF}$$

  - $\boldsymbol{V}$: matrix of value added coefficient where elements $v_i = va_i / y_i$
  - $\boldsymbol{L}$: Leontif matrix
  - $\boldsymbol{F}$: diagonal matrix of final demands
  - Narrow measure: focus on column side of the matrix $\boldsymbol{S}$
  - Broad measure: *DVA* is sum of that country-sector row

Sample and Stylized Facts

Sample

Descriptive statistics of the panel dataset, 2008-2019

Variable	Description	Standard deviation			Observations		Mean
		Overall	Between	Within	Nb of obs	Nb of countries	
RES	Reshoring (Narrow)	0.53	0.11	0.51	744	62	-0.02
LGAUTO	Auto adopt by pop (Log)	1.56	1.56	0.23	744	62	8.35
LGCAD	CAD/CAM by pop (Log)	1.07	1.04	0.27	744	62	1.56
LGICT	ICT by pop (Log)	1.81	1.80	0.27	744	62	4.82
LGREGINST	Reg Instru by pop (Log)	1.27	1.26	0.22	744	62	2.16
LGROBOTS	Robots by pop (Log)	1.32	1.30	0.29	744	62	2.46
LGWEL	Welding by pop (Log)	0.62	0.56	0.27	744	62	0.75
LG3D	3D printing by pop (Log)	1.07	1.05	0.25	744	62	2.00
LGPAT	Patents by pop (Log)	0.03	0.03	0.01	744	62	0.02
LGLBPROD	LP (Log)	0.85	0.85	0.09	744	62	3.30
LANDLOCKED	Dummy landlocked	0.40	0.40	0	744	62	0.19
LNTEMP	Temperature (Log)	0.29	0.29	0	720	60	3.47

Stylized Facts

- **Reshoring fluctuates over time from 2008 to 2019, shows different pattern than the measure from** Krenz et al., 2021

Figure 1: New reshoring index in China (PRC), Great Britain (UKG), Spain (SPA), and United States (USA)

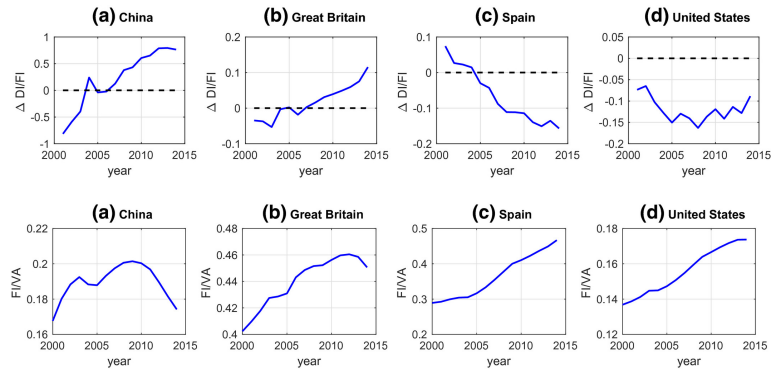


Figure 2: Reshoring index by Krenz et al., 2021 in China, Great Britain, Spain and United States (USA). Source: Krenz et al., 2021

Stylized Facts

- **Reshoring fluctuates over time from 2008 to 2019**

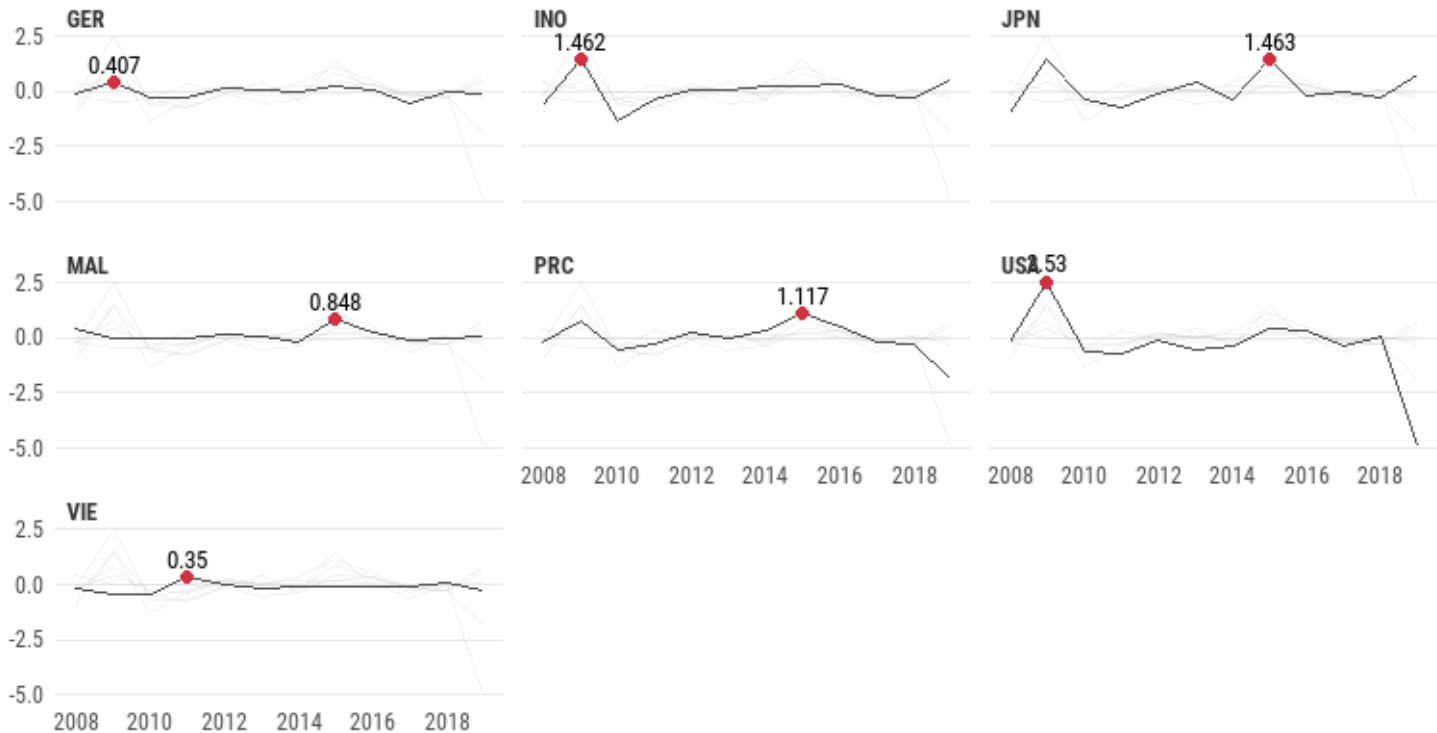


Figure 3: Reshoring (Narrow) by country over time

Stylized Facts

- **Different magnitudes over time and across sectors**

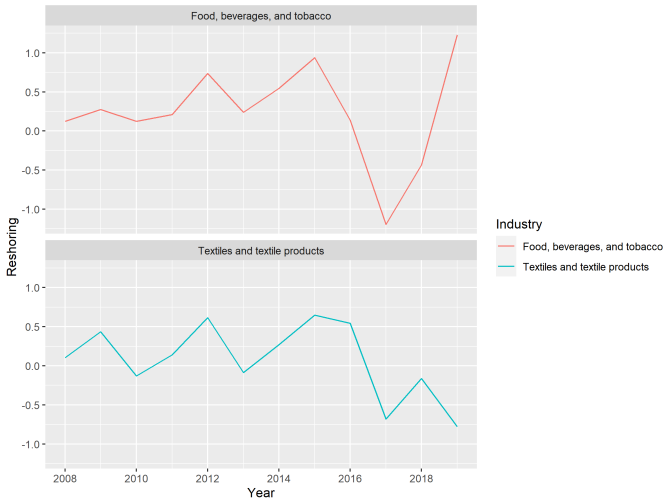


Figure 4: New reshoring index at industry level in China in Food and Textiles industry

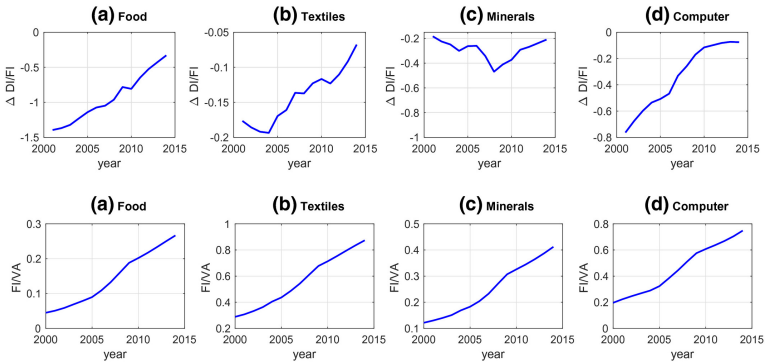


Figure 5: Reshoring index by Krenz et al., 2021 at sector level in China. Source: Krenz et al., 2021

Stylized Facts

- **Automation Adoption**

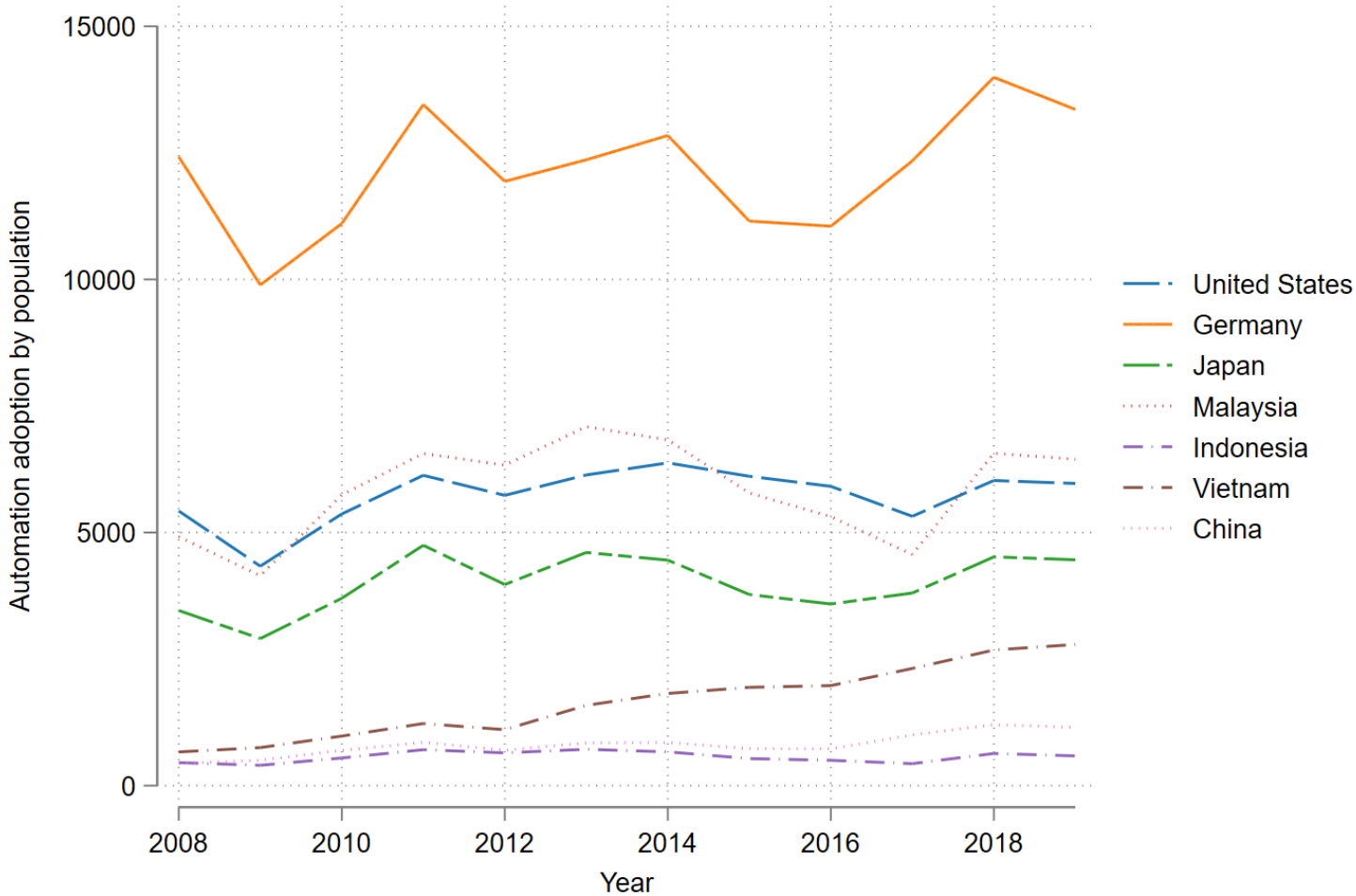


Figure 6: Automation Adoption by country over time

Stylized Facts

- **Different types of technologies show different trends of adoption**

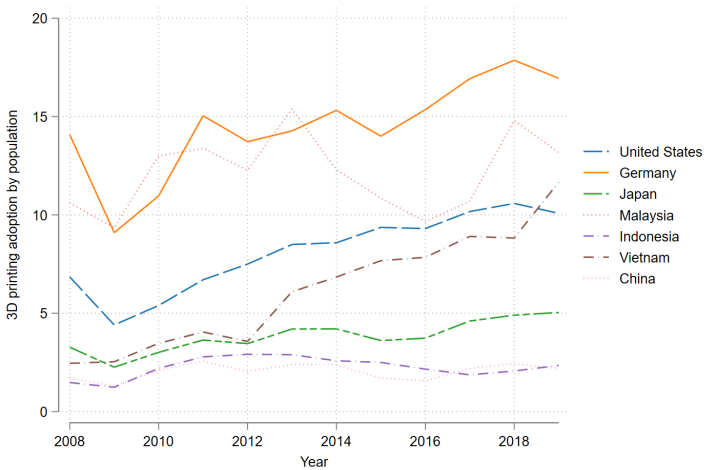


Figure 7: 3D printing adoption by country over time

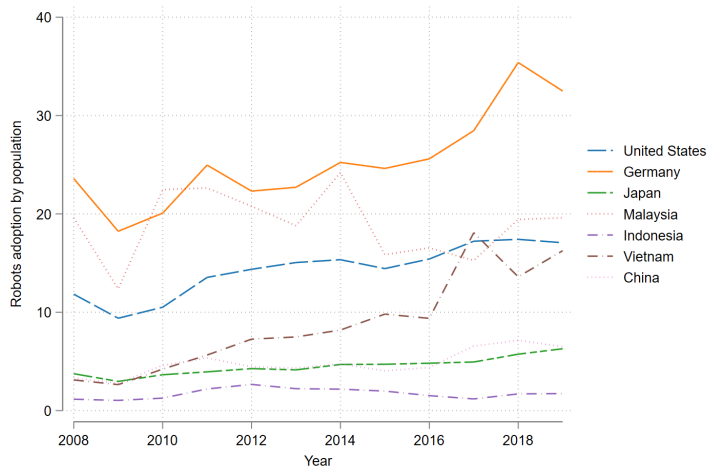


Figure 8: Robots adoption by country over time

Empirical Strategy

At cross-country level

$$RES_{ct} = \beta_0 + \beta_1 LGAUTO_{ct} + \beta_2 LGPAT_{ct} + \beta_3 LGLBPROD_{ct} + \beta_4 LGDIS + \beta_5 LANDLOCKED + \beta_6 LNTEMP + \beta_7 D_t + \varepsilon_{ct}$$

- c: country, t: time period, ε_{ct}: error term
- RES_{ct}: reshoring in country c at time t, measured at narrow definition
- $LGAUTO_{ct}$: logarit form for total automation imports value at country c at time t; weighted by population
- $LGPAT_{ct}$: logarit form for number of patents for 10 years accumulation in country c at time t, weighted by population
- $LGLBPROD_{ct}$: logarit form for labour productivity at country c at time t

At sector-country level

$$RES_{ict} = \beta_0 + \beta_1 LGPAT_{ict} + \beta_2 LGAUTO_{ict} + \beta_3 LGLBPROD_{ict} + \beta_4 LGDIS + \beta_5 LANDLOCKED + \beta_6 LNTEMP + \beta_7 D_t + \varepsilon_{ct}$$

- i is industry, c is country, t is time period and ε_{ict} is the error term
- Mitigate the endogeneity problems that arise in cross-country regressions by assuming that it is unlikely that strong sectoral reshoring causes changes in the country-level determinants

Results

At cross-country level: Baseline Results

Does automation adoption **increase** reshoring at the macro level? No

Variable	Random effects Coef	SE	Sig	Fixed effects Coef	SE	Sig	Hausman-Taylor Coef	SE	Sig
LGAUTO*	-0.012	0.011		-0.302	0.095	***	-0.303	0.109	***
LGPAT	-0.406	0.487		-2.90	2.71		0.01	-2.708	2.045
LGLBPROD*	0.077	0.027	***	0.45	0.40		0.09	0.462	0.322
LGDIST	0.013	0.027		(Dropped)			-0.118	0.110	
LAND	-0.019	0.034		(Dropped)			-0.029	0.184	
LNTEMP	0.052	0.071		(Dropped)			-0.181	0.445	
D2009	0.562	0.115	***	0.518	0.114	***	0.518	0.093	***
D2010	-0.122	0.067	*	-0.122	0.069	*	-0.123	0.092	
D2011	-0.105	0.052	**	-0.050	0.055		-0.050	0.095	
D2012	0.124	0.058	**	0.137	0.062	**	0.136	0.093	
D2013	0.111	0.053	**	0.153	0.059	**	0.152	0.095	
D2014	0.059	0.051		0.098	0.065		0.096	0.096	
D2015	0.381	0.087	***	0.376	0.105	***	0.373	0.097	***
D2016	0.140	0.068	**	0.122	0.087		0.118	0.098	
D2017	-0.101	0.061	*	-0.104	0.080		-0.108	0.100	
D2018	-0.023	0.060		0.014	0.081		0.010	0.103	
D2019	0.006	0.140		0.028	0.167		0.024	0.105	
Nb of obs	720			720			720		
Nb of coun	60			60			60		
R^2 *within*	0.14			0.15					
R^2 *between*	0.15			0.0004					
R^2 *overall*	0.14			0.06					

At cross-country level: Adding interaction effects

Is this a **linear relationship**? No

	With AUTODUMMY			With AUTOPAT and AUTODUMMY			With AUTOPROD and AUTODUMMY		
Variable	Coef	SE	Sig	Coef	SE	Sig	Coef	SE	Sig
LGAUTO*	-0.349	0.113	***	-0.358	0.115	***	-0.114	0.120	
LGPAT	-4.315	1.768	**	-2.234	67.789		-15.484	11.715	
LGPROD*	0.638	0.228	***	0.477	0.377		1.518	0.786	*
AUTODUM	0.215	0.124	*	0.407	0.222	*	0.706	0.300	**
AUTOPAT				-1.535	7.136				
AUTOPROD							-0.139	0.093	
LGDIST	-0.014	0.049		(Dropped)			(Dropped)		
LAND	0.046	0.118		(Dropped)			(Dropped)		
LNTEMP	0.079	0.199		(Dropped)			(Dropped)		
Nb of obs	720			720			720		
Nb of coun	60			60			60		
R^2 *within*				0.16			0.16		
R^2 *between*				0.0003			0.00		
R^2 *overall*				0.06			0.04		

Model with interaction term AUTODUMMY is Hausman Taylor specification. Models with interaction term AUTODUMMY and AUTOPAT, and AUTODUMMY and AUTOPROD are fixed effects specification. * p<0.1; ** p<0.05; *** p<0.01

At cross-country level: Adding interaction effects

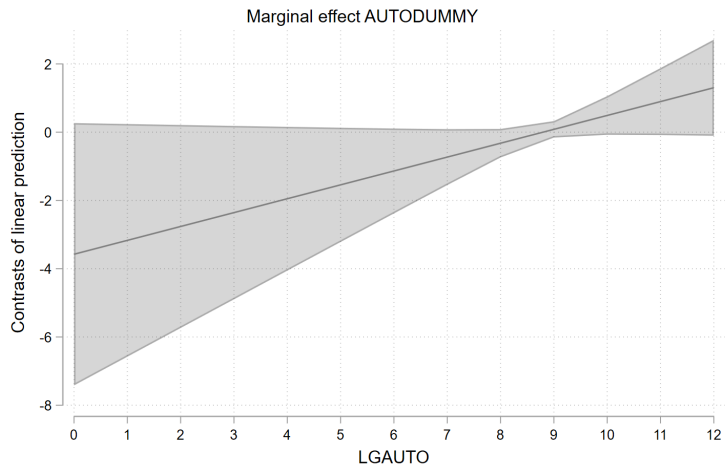


Figure 9: The marginal effect of AUTODUMMY on reshoring

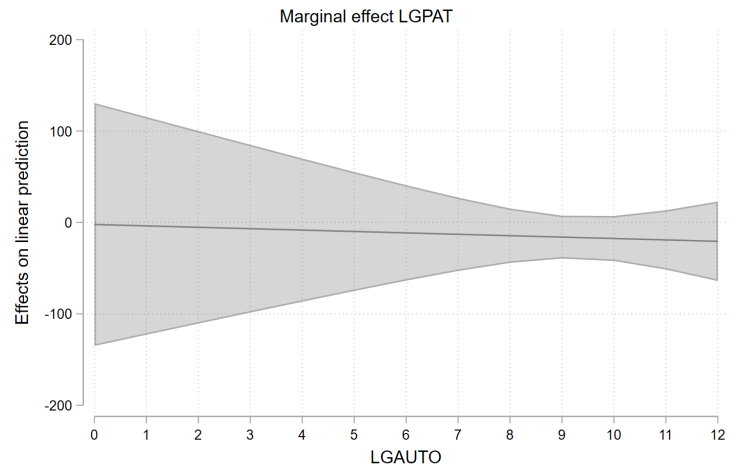


Figure 10: The marginal effect of LGPAT on reshoring

Model with interaction term AUTODUMMY and AUTOPAT (Fixed effects)

At cross-country level: Adding interaction effects

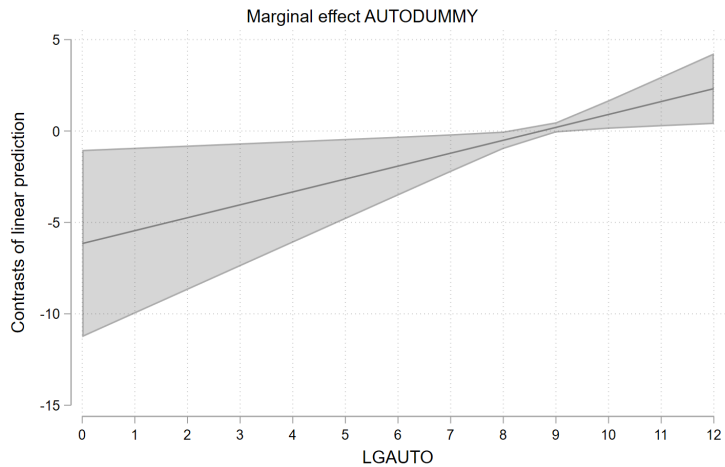


Figure 11: The marginal effect of AUTODUMMY on reshoring

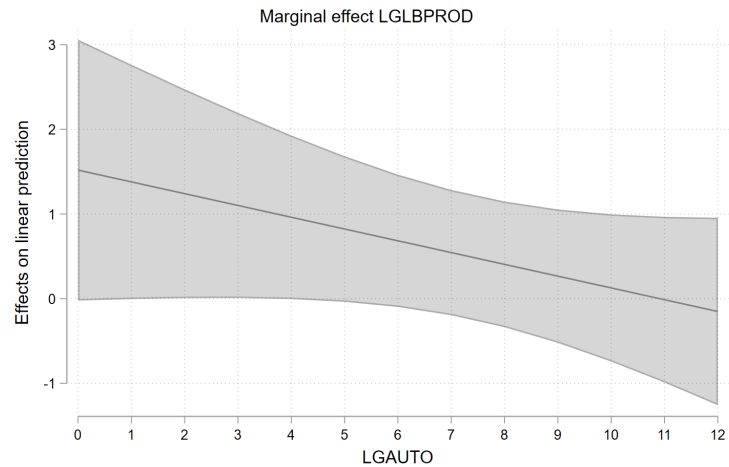
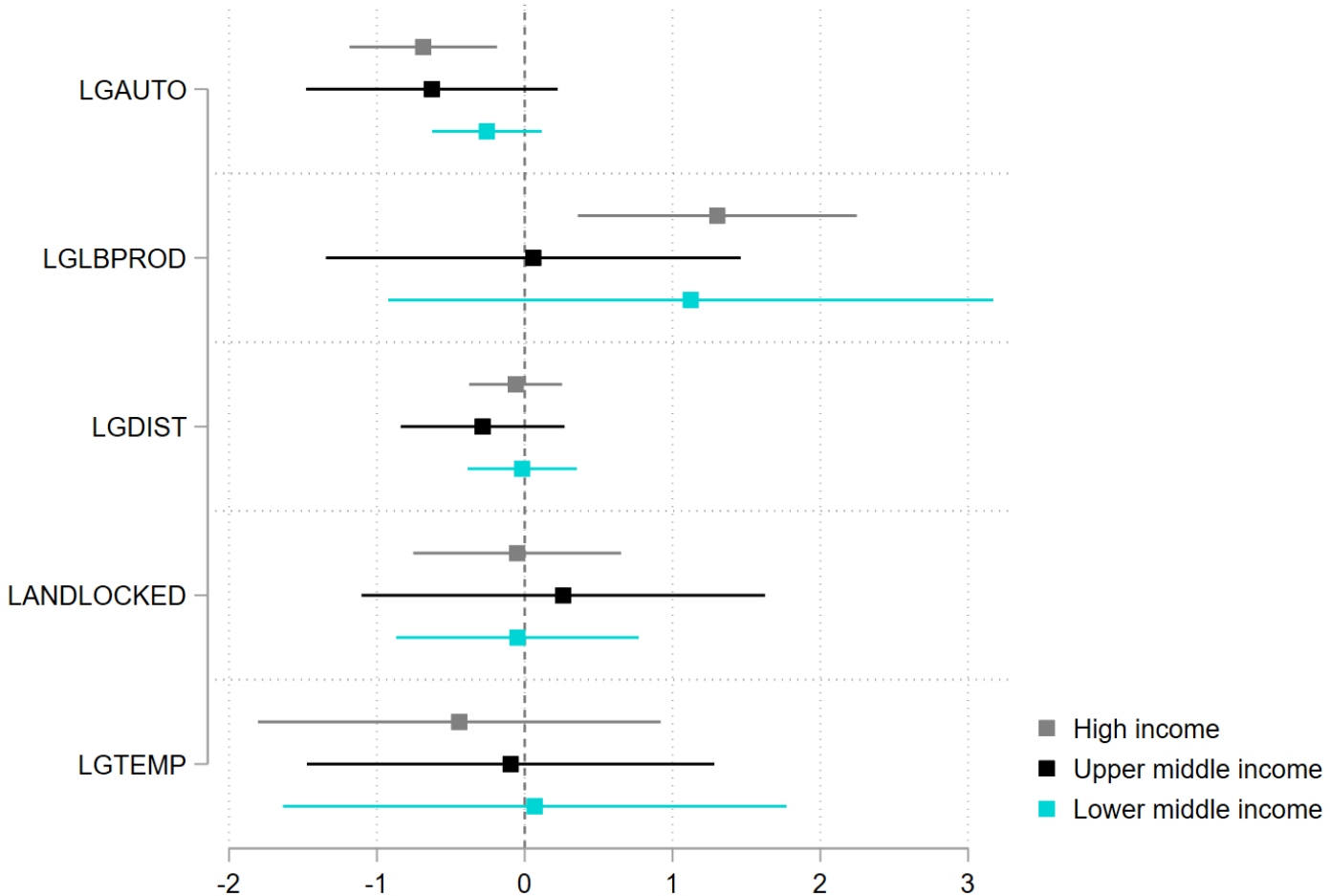


Figure 12: The marginal effect of LGLBPROD on reshoring

Model with interaction term AUTODUMMY and AUTOPROD (Fixed effects)

At cross-country level: Income effects

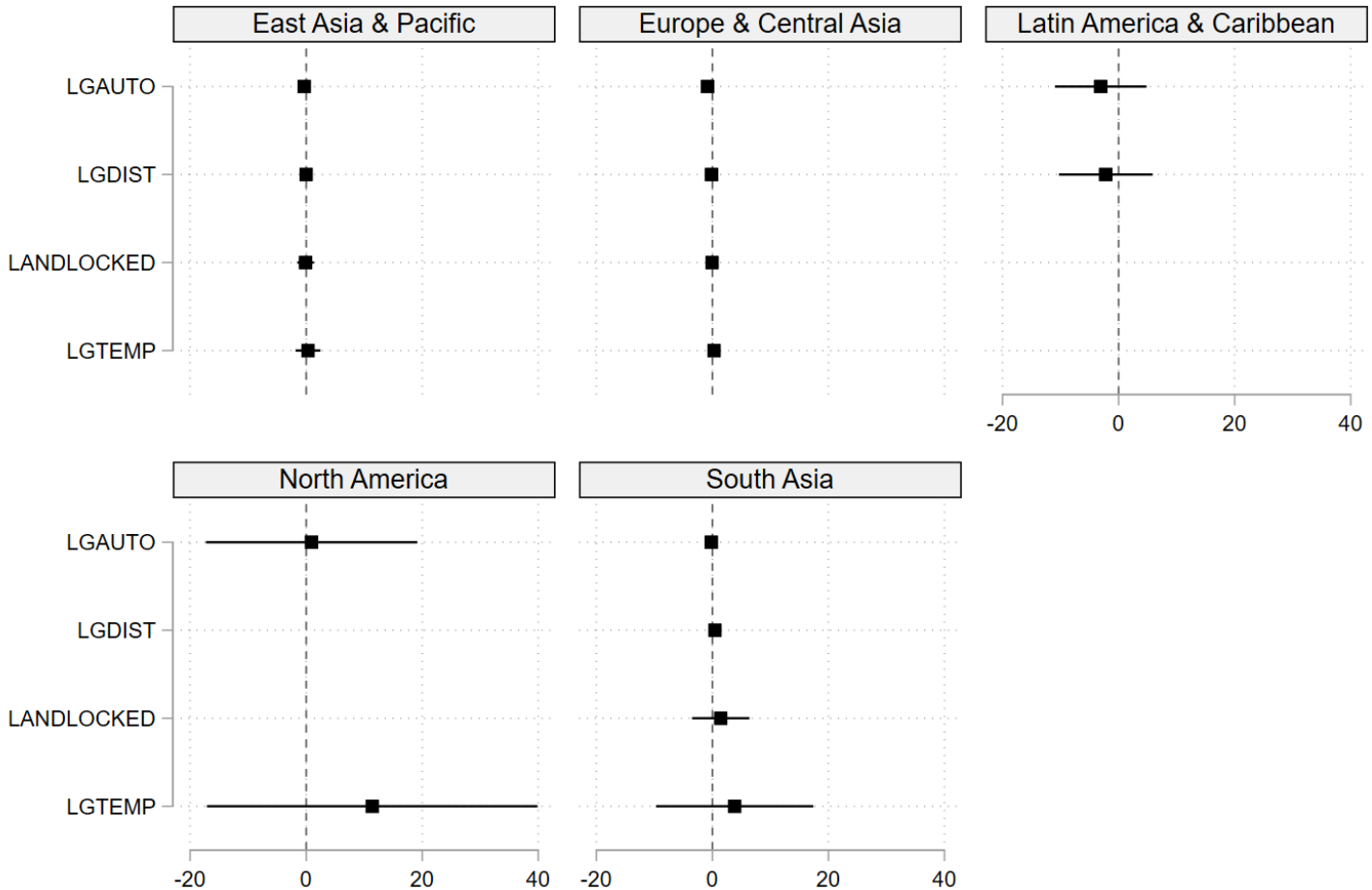
Does this effect differ between **high-income, middle-income, lower-middle-income countries**? Yes



Model with interaction term AUTODUMMY (Hausman-Taylor specification)

At cross-country level: Regions effects

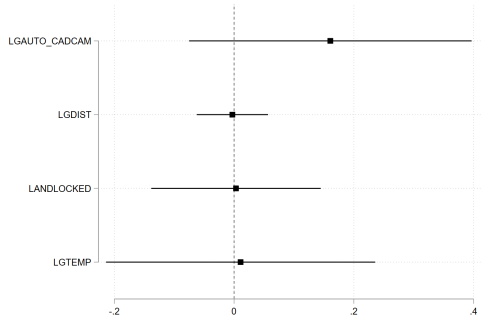
Does this effect differ between **regions**? Yes



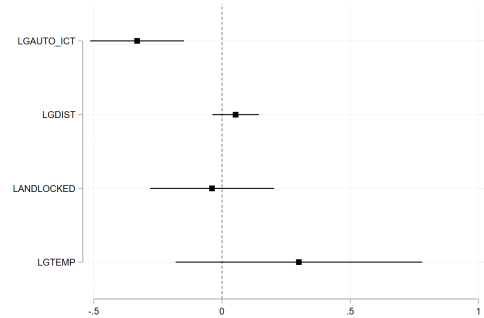
Model with interaction term AUTODUMMY (Hausman-Taylor specification)

At cross-country level: Types of technologies

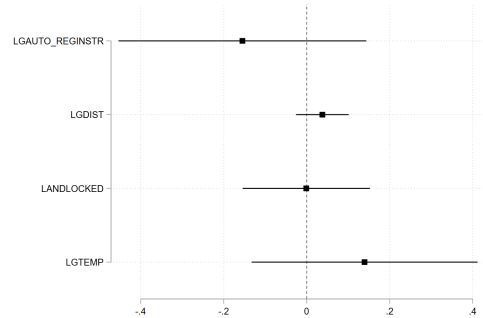
Is there different effect for **type of technologies?** Yes



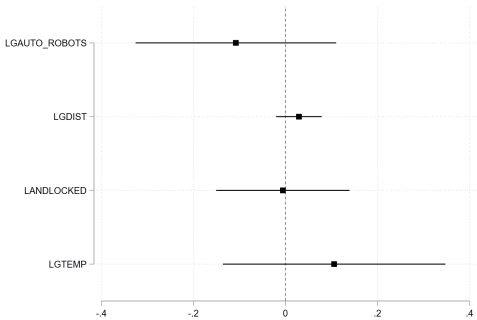
((a)) CAD/CAM



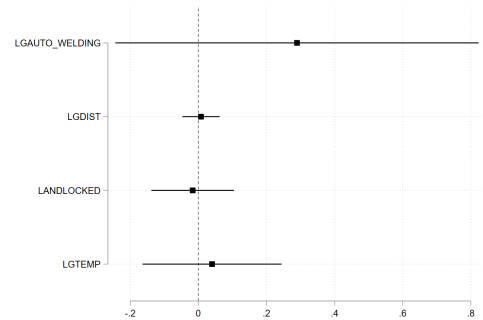
((b)) ICT



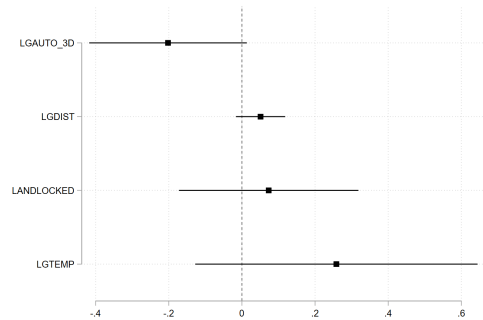
((c)) Reg Instruments



((d)) Robots



((e)) Welding

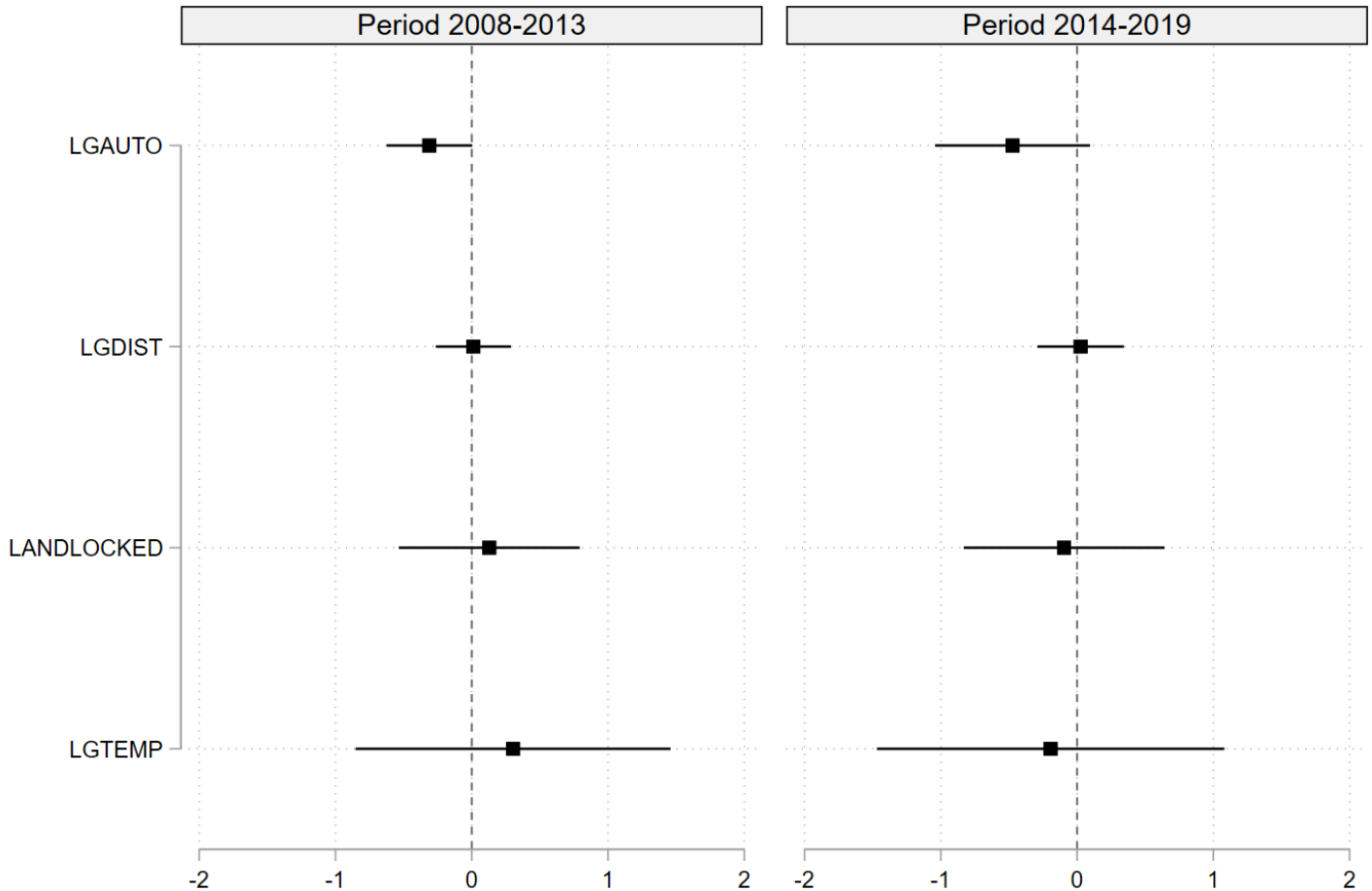


((f)) 3D Printing

Figure 13: Types of technologies

At cross-country level: Time effects

Does this effect **vary over time**? Yes



Summing up

- Reshoring is **not a common trend** in the period 2008-2019
- We look at the impact of automation:
  - Automation adoption is **not associated by an increase in reshoring**, but even promote offshoring
  - **Marginal effect of automation adoption** reducing reshoring is greater for countries adopt more automation technologies
  - This effect is driven by **high income countries**
  - **Europe Central Asia** and **East Asia Pacific** are the two regions driving this effect - confirm the importance of regional connection
  - **ICT and 3D Printing** are the two only technologies confirming this effect
  - **No effect** found for **period 2014-2019**