# International Relocation of Production and Cross-Country Growth

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# Introduction (I)

#### • Relocation of production from high- to low-income countries:

- Apparently, a key feature of the increase in economic globalization over the last decades.
- Potential result of many different phenomena:
  - Product life cycle, offshoring: Vernon (1966), Krugman (1979), Grossman and Helpman (1991), Antrás (2005), Acemoglu, Gancia and Zilibotti (2012), etc..
  - ★ International fragmentation of production: Feenstra (1998), Hummels, Ishii and Yi (2001), Koopman, Wang and Wei (2014).
- Not a one-way phenomenon: product innovation and increasing technical sophistication can relocate the production of goods (as defined by 6-digit HS classification) to higher-income countries.

#### • Questions:

- What are the dynamics of international production relocation?
- In which sectors is the relocation more widespread and intense? In which direction are they moving? Do their dynamics change over time?
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# Introduction (II)

• Previous research on production relocation and its impact on growth

 limited to <u>specific sectors or countries</u> (e.g., Sturgeon et al., 2008; Timmer et al., 2015).

#### • This paper's contribution:

- Global analysis of the relocation process across all the products (using 6-digit data; up to 5,000 products).
- Assessment of its impact on growth across a large sample of countries (more than 100 countries).

- We build on Hausmann, Hwang and Rodrik (2007) (HHR) and develop their indices to study relocation and its impact on growth.
- This is an ongoing research; preliminary results for 1995-2007.

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### Preview of the results

#### The international relocation of production

- Rather surprisingly, no intensification between 1995 and 2007.
  - \* However, great heterogeneity in the dynamics across sectors.
  - $\star\,$  Pending in the project: extending the period of analysis.
- The impact on cross-country growth
  - Countries that were specialized at the beginning of the period in products relocating towards lower-income (higher-income) exporters over the subsequent decade, had lower (greater) growth.

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### Measuring international production relocation

• Reinterpreting Hausmann, Hwang and Rodrik (2007) (HHR) measures of product and export sophistication.

The product's position in the ladder of exporters' income

$$PRODY_{k}^{t} = \sum_{j} \frac{RCA_{kj}^{t}}{\sum_{j} RCA_{kj}^{t}} y_{j}^{t};$$

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- i.e., a weighted average of exporters' per capita GDP.
  - stage in the product's life cycle.

Product (k) relocation along the exporters' income ladder  $g(prody_k^{t+1}) = \ln \frac{PRODY_k^{t+1}}{PRODY_k^t}.$ 

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#### Measuring the intensity of the international relocation

• Higher production relocation across the exporters' income groups implies higher dispersion of the PRODY's growth rates.

Mean Absolute Deviation (MAD) of the PRODYs' Growth Rates

$$MAD\left(g\left(prody^{t+1}\right)\right) = \sum_{k=1}^{K} \left|g\left(prody_{k}^{t+1}\right) - g\left(prody^{t+1}\right)\right| \frac{\omega_{kW}^{t} + \omega_{kW}^{t+1}}{2}$$

 Advantage of the MAD measure over other candidates such as Standard Deviation: Additivity

$$\begin{split} MAD(g\left(\text{prody}^{t+1}\right)) &= \sum_{s=1}^{S} MAD\left(g\left(\text{prody}^{t+1}_{s}\right)\right) \frac{\omega_{sW}^{t} + \omega_{sW}^{t+1}}{2},\\ \text{where } MAD\left(g\left(\text{prody}^{t+1}_{s}\right)\right) &= \\ \sum_{k \in s} \left|g\left(\text{prody}^{t+1}_{k}\right) - g\left(\text{prody}^{t+1}\right)\right| \frac{\omega_{sW}^{t} + \omega_{sW}^{t+1}}{\omega_{sW}^{t} + \omega_{sW}^{t+1}} \\ \end{bmatrix} \end{split}$$

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#### The data

- 6-digit (up to 5,000 products), 2-digit (96 industries) and 1-digit (18 sectors) data for bilateral trade from BACI (Base pour l'Analyse du Commerce International), a database provided by CEPII (Centre d'Études Prospectives et d'Informations Internationales).
  - Harmonized System (HS)-1992 classification.
  - The reference sample includes 136 countries, which corresponds to a consistent sample of countries offering trade information for the complete period 1995-2007 and with population size over 500,000.
  - Following HHR, PRODYs calculated averaging data of 3 years.
  - Data are from 1995 to 2007 to avoid the Great Recession.
    - ★ Thus, indices from 1996 to 2006 and growth rates 1997-2006.
- GDP per capita, in 2005 prices PPP, from World Bank's WDI.

#### Dynamics of the International Relocation of Production

Relocation intensity as measured by the MAD of the PRODY rates of change



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**Relocation intensity** 

## Some facts about the intensity of the relocation process

- The intensity of the relocation process at the 6-digit level more than doubles the intensity at the 2- or 1-digit level.
  - Fragmentation of production: the average exporter of a 2-digit industry might not change while some of this industry's 6-digit products move upwards and downwards along the exporters' income ladder.
- Rather surprisingly, no intensification between 1995 and 2007.
- However, great heterogeneity across sectors.
  - Highest overall MAD indices: Pharmaceuticals, Transport equip. exc. cars, Metals and manuf. exc. iron, Textiles and footwear, Animal products, Food, beverage and tobacco.
  - Highest contributions to overall international relocation of production : Minerals, Machinery and mechan. appl. Textiles, Electrical equipment, Chemicals (exc. Pharma), Metals and their manuf. (exc. iron).
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### Sector Contributions to the Intensity of Relocation

Mean Absolute Deviations (MAD) of the 6-digit PRODYs rates of growth, using as reference the average growth of all the PRODYs in the economy

Sector	Contribut to MAD 1996-2006	Weight in world trade 1996-2006	MAD PRODY growth 1996-2006	
Minerals	12.5	11.7	1.73	
Machinery and mech appl.	11.6	14.8	1.26	
Textiles, footwear, leather	10.3	7.8	2.12	
Electrical equipment	9.2	12.3	1.21	
Chemicals exc. Pharma	7.0	6.5	1.73	
Metals and manuf. exc. Iron	5.6	3.6	2.50	
Iron and manufact. thereof	5.3	4.8	1.77	
Motor vehicles	4.8	9.8	0.80	
Wood and paper	4.5	3.8	1.88	
Food, beverage and tobacco	4.2	3.4	2.00	
Plastics	3.9	4.6	1.39	
Transport equip. exc. cars	3.9	2.4	2.64	
Pharmaceuticals	3.4	2.0	2.82	
Other sectors	3.1	1.4	3.56	
Animal products	2.9	2.3	2.11	
Furniture, stone and others	2.8	3.4	1.35	
Vegetable products	2.5	2.7	1.51	
Instruments	2.3	2.8	1.34	
Total economy	100	100	1.61	

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## International Relocation of Production by Sector

Sector	Annual PRODY growth 96-06	Annual PRODY growth 96-01	Annual PRODY growth 01-06	Average PRODY	
Pharmaceuticals	4.22	4.9	3.5	21,966	
Transport equip. exc. cars	2.77	2.1	3.5	16,368	
Wood and paper	2.44	2.3	2.6	16,789	
Iron and manufact. thereof	2.31	1.4	3.1	14,750	
Chemicals exc. Pharma	2.31	2.0	2.5	19,609	
Animal products	2.23	1.5	3.0	14,271	
Food, beverage and tobacco	2.09	2.0	2.2	12,183	
Instruments	1.72	2.1	1.5	21,570	
Furniture, stone and others	1.66	0.8	2.7	14,855	
Machinery and mech appl.	1.33	1.3	1.4	20,615	
Vegetable products	1.31	1.3	1.3	9,427	
Plastics	1.26	1.6	1.0	18,604	
Electrical equipment	1.17	0.6	1.7	18,046	
Motor vehicles	1.08	0.5	1.4	20,311	
Metals and manuf. exc. Iron	1.07	0.0	1.9	15,009	
Textiles, footwear, leather	1.06	0.1	1.9	8,905	
Minerals	0.91	-0.2	1.9	11,921	
Other sectors	0.32	-1.5	1.8	7,771	
Whole economy	1.5	1.04	1.94		

### Some Facts

#### • Heterogeneity across sectors:

- Largest downwards relocations (towards lower-income countries): Minerals, Textiles, Metals and their manuf. (exc. Iron), Motor vehicles, Electrical equipment, Plastics.
- Largest upwards relocations: Pharmaceuticals Transport equip. (exc. cars), Wood and paper, Iron manufact., Chemicals (exc. Pharma).
- **Predictability of the changes** in the products' sophistication indices (i.e., in their position in the exporters' income ladder):
  - They are (very slightly) negatively correlated with initial sophistication (significant but very low elasticity).

#### Initial sophistication (PRODY) and relocation 1997-2006 6-digit products



## Impact on Growth: Informal Theoretical Model

- The production of each good involves specific knowledge and skills.
  Process innovations as well as standardization occur randomly across sectors and products:
  - In the case of product innovations in an industry, the value of these skills and knowledge increases.
    - \* It is easier for countries with these production factors to produce the new varieties whose production is (temporarily) more profitable.
  - If standardization of production and offshoring, their value decreases.
    - \* The product's world supply will expand at lower prices.
  - It is difficult for governments to predict when and where will they occur.
- The increase (resp. decrease) in a good's PRODY is a sign of the intensity of product innovation (resp. standardization).
- Therefore, when a product experiences a wave of innovation (standardization), lucky (unlucky) countries that happen to be specialized in these products beforehand will grow faster (slower).

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## Measuring the Impact on Cross-Country Growth

• HHR (2007) index of country j's export sophistication at t = 0:  $EXPY_j^0 = \sum_k PRODY_k^T \omega_{kj}^0$ 

where T is the year at the end of the period of the analysis.Decomposing the two effects on growth:

(Pure) Initial *IEXPY*'s using the initial period *PRODY*'s  $IEXPY_j^0 = \sum_k PRODY_k^0 \omega_{kj}^0$ 

Measuring the impact of IPR on country j's export sophistication

IPR Impact on j'sophistication =  $\frac{EXPY}{IEXPY}$ 

• For the econometrics:  $\ln(EXPY_j^0) = \ln(IEXPY_j^0) + \ln\left(\frac{EXPY_j^0}{IEXPY_j^0}\right)$ 

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# pcGDP and Countries' Relocation Impact Indices EXPY/IEXPY



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#### Countries' Relocation Impact Indices and Growth



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### Econometric Strategy

• Main specification:

$$\frac{1}{T}\ln\frac{y_j^T}{y_j^0} = \beta_0 + \beta_1 \ln y_j^0 + \beta_2 \ln(IEXPY_j^0) + \beta_3 \ln\left(\frac{EXPY_j^0}{IEXPY_j^0}\right) + \beta_4 X_j^0 + u_j$$

where  $X_j^0$  is a vector of controls (human capital and rule of law) and  $u_j$  is the error term.

• Sample: 111 countries (from 136) after using data for human capital (Barro&Lee) and rule of law (WGI) and removing countries undergoing large civil wars and ethnic conflicts.

### Econometric Strategy: IV estimations

- Potential problem of circularity in the use of a country's data to determine product sophistication that explains the country's per capita income.
  - Country j's specific PRODYs excluding countryj's data:

$$CSPRODY_{k,-j}^{t} = \sum_{i \neq j} \frac{exports_{ki}^{t} / exports_{i}^{t}}{\sum_{i \neq j} \left(exports_{ki}^{t} / exports_{i}^{t}\right)} y_{i}^{t}$$

Then, using the CSPRODY's to define specific prody EXPY and IEXPY:

$$SPEXPY_{j}^{0} = \sum_{k} CSPRODY_{k-j}^{T} \omega_{kj}^{0}$$
$$SPIEXPY_{j}^{0} = \sum_{k} CSPRODY_{k-j}^{0} \omega_{kj}^{0}$$

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# Results: OLS

Table 4. Cross-country growth regressions, 1995-2007 (OLS)					
Dependent variable:					
Growth					
rate of GDP per capita					
	(1)	(2)	(3)	(4)	
log initial GDP pc	-0.0176***	-0.0166***	-0.00521**	-0.0129***	
	(0.00389)	(0.00457)	(0.00248)	(0.00448)	
log EXPY	0.0311***				
	(0.00690)				
log human capital	0.00633***	0.00709***	0.00554**	0.00527**	
	(0.00218)	(0.00230)	(0.00263)	(0.00229)	
Rule of law	0.00388*	0.00485*	0.000447	0.00143	
	(0.00231)	(0.00254)	(0.00211)	(0.00217)	
Log IEXPY		0.0264***		0.0214***	
		(0.00835)		(0.00807)	
log EXPY/IEXPY			0.103***	0.0924***	
			(0.0217)	(0.0211)	
Constant	-0.125***	-0.0888*	0.0451**	-0.0813*	
	(0.0403)	(0.0463)	(0.0187)	(0.0438)	
Observations	111	111	111	111	
$\mathbb{R}^2$	0.271	0.208	0.272	0.329	

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#### Partial correlation plots



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Quantitative effect

- Both IEXPY and EXPY/IEXPY have a positive, significant and quantitatively important impact on economic growth:
  - An increase in IEXPY of one standard deviation of ln(IEXPY) (i.e., 0.48) raises annual per capita GDP growth by 1.03 percent. points.
  - An increase in ln(EXPY/IEXPY) of one standard deviation (i.e., 0.083) increases the annual growth rate by 0.77 percent. points.
  - Going from the 1st to the 3rd quartile along the distribution of IEXPY increases annual per capita GDP growth by 1.67 points.
  - Going from the 1st to the 3rd quartile along the distribution of In(EXPY/IEXPY) increases annual growth by 0.66 percent. points.

## **IV** Estimations

Table 5. Cross-country growth regressions, 1995-2007 (IV)					
Dependent variable: Growth rate of GDP per capita					
	(1)	(2)	(3)	(4)	
log initial GDP pc	-0.0162***	-0.0161***	-0.00569**	-0.0125***	
	(0.00383)	(0.00448)	(0.00257)	(0.00467)	
log EXPY	0.0269***				
	(0.00673)				
log human capital	0.00651***	0.00712***	0.00604**	0.00579**	
	(0.00215)	(0.00225)	(0.00267)	(0.00234)	
Rule of law	0.00391*	0.00480*	0.00129	0.00214	
	(0.00226)	(0.00249)	(0.00230)	(0.00231)	
log IEXPY		0.0250***		0.0189**	
		(0.00814)		(0.00823)	
log EXPY/IEXPY			0.0789***	0.0705***	
			(0.0229)	(0.0217)	
Constant	-0.0985**	-0.080*	0.0510***	-0.0609	
	(0.0395)	(0.0454)	(0.0194)	(0.0422)	
Observations	111	111	111	111	
R <sup>2</sup>	0.268	0.208	0.263	0.321	
F-statistic	1828.42	1580.69	83.39	1266.09	
				69.92	

### Export Openness and the Impact of Relocation

- For export sophistication to matter, the country has to export!
  - $\blacktriangleright \Longrightarrow$  We should include interactions with export intensity.
- New econometric specification:

$$\frac{1}{T}\ln\frac{y_j^{\ l}}{y_j^0} = \beta_0 + \beta_1 \ln y_j^0 + \beta_2 [\ln(IEXPY_j^0) * \ln(ExportIntensity_j^0)] \\ + \beta_3 [\ln\left(\frac{EXPY_j^0}{IEXPY_j^0}\right) * \ln(ExportIntensity_j^0)] \\ + \beta_4 \ln(ExportIntensity_j^0) + \beta_5 X_j^0 + u_j$$

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# Export Openness and the Impact of Relocation

Table 6. Cross-country growth regressions. 1995-2007						
Dependent variable: Growth rate of pcGDP	OLS			IV		
crowal fact of proble	(1)	(2)	(3)	(4)	(5)	(6)
log initial GDP pc	-0.0142***	-0.0127***	-0.0139***	-0.0139***	-0.0120***	-0.0135***
0	(0.00424)	(0.00455)	(0.00429)	(0.00435)	(0.00451)	(0.00437)
log human capital	0.00559**	0.00531**	0.00569**	0.00614***	0.00578**	0.00615***
	(0.00235)	(0.00243)	(0.00238)	(0.00232)	(0.00237)	(0.00232)
Rule of law	0.00141	0.00135	0.00135	0.00217	0.00189	0.00201
	(0.00214)	(0.00218)	(0.00213)	(0.00218)	(0.00222)	(0.00217)
log IEXPY		0.0211**			0.0181**	
		(0.00823)			(0.00798)	
log EXPY/IEXPY	0.0902***			0.0672***		
	(0.0210)			(0.0210)		
logIEXPY*log ExportIntens	0.00726***		0.00712***	0.00664***		0.00643***
	(0.00219)		(0.00221)	(0.00226)		(0.00227)
log(EXPY/IEXPY)*log						
ExportIntens		0.0253***	0.0246***		0.0205***	0.0191***
		(0.00600)	(0.00582)		(0.00560)	(0.00558)
log ExportIntensity	-0.0663***	-0.00290	-0.0682***	-0.0610***	-0.00266	-0.0616***
	(0.0203)	(0.00271)	(0.0204)	(0.0211)	(0.00260)	(0.0210)
Constant	0.125***	-0.0698	0.134***	0.125***	-0.0486	0.130***
	(0.0360)	(0.0454)	(0.0358)	(0.0375)	(0.0427)	(0.0367)
Observations	111	111	111	111	111	111
_R <sup>2</sup>	0.359	0.333	0.361	0.350	0.326	0.353

#### Export Openness and the Impact of Relocation Quantitative implications

- Both IEXPY and EXPY/IEXPY are positive and significant when interacted with export intensity.
  - The marginal effect of lnIEXPY and ln(EXPY/EXPYI) depend on the country's export intensity. At the median value of log export intensity (3.44, thus exports representing 31% of country's GDP):
    - An increase in IEXPY of one standard deviation of In(*IEXPY*) (i.e., 0.48) would raise per capita GDP growth by 1.2 percent. points.
    - An increase in ln(EXPY/IEXPY) of one standard deviation (i.e., 0.083) would increase the annual growth rate by 0.7 percentage points.
    - going from the 1st to the 3rd quartile along the distribution of InIEXPY increases annual pcGDP growth by 1.9 percentage points.
    - going from the 1st to the 3rd quartile along the distribution of InEXPY / IEXPY increases pcGDP growth by 0.6 percent. points.
  - Almost identical results using other indicators of openness such as (export+imports)/GDP, real openness or real export openness (using PPP per capita GDP in the denominator).

## Summary and Concluding Comments

International relocation of production over the period 1995-2007:

- Surprisingly, constant relocation intensity over the period.
  - ★ However, very heterogeneous across sectors.
- We identify the intensity and direction of production relocation across sectors and products.
- Interimpact of relocation on cross-country growth
  - Countries specialized in 1995 in products showing a relocation process towards low-income (advanced) economies over the ensuing 1995-2007 period, exhibit significantly lower (greater) growth over that period.
  - The quantitative impact of this effect increases with the economy's export intensity.