Offshoring and Skill-upgrading in French Manufacturing: A Heckscher-Ohlin-Melitz View

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Motivation

- How does international trade affect the demand for skilled relative to unskilled workers in industrialized countries?
- Heckscher-Ohlin (HO) theory has traditionally focused on between-industry effects – skill-abundant countries specialize in skill-intensive sectors.
- However,
  - Crucial assumption of HO model that variation in factor intensities is between industries is violated: large variation in firm-level skill intensities within 4-digit industries (e.g. Corcos et al., 2013).
  - Most of the increase in skill intensities has occurred within firms despite higher skill premia.
- We build a theoretical model and test its predictions on sourcing patterns and domestic skill demand using a quasi-exhaustive panel of French manufacturing firms from 1996-2007.

Outline of the talk

1. Descriptive evidence
2. Model: brief description and main predictions
3. Data
4. Empirical results (OLS, IV in annex)
5. Conclusions

Within-sector variation in skill intensity

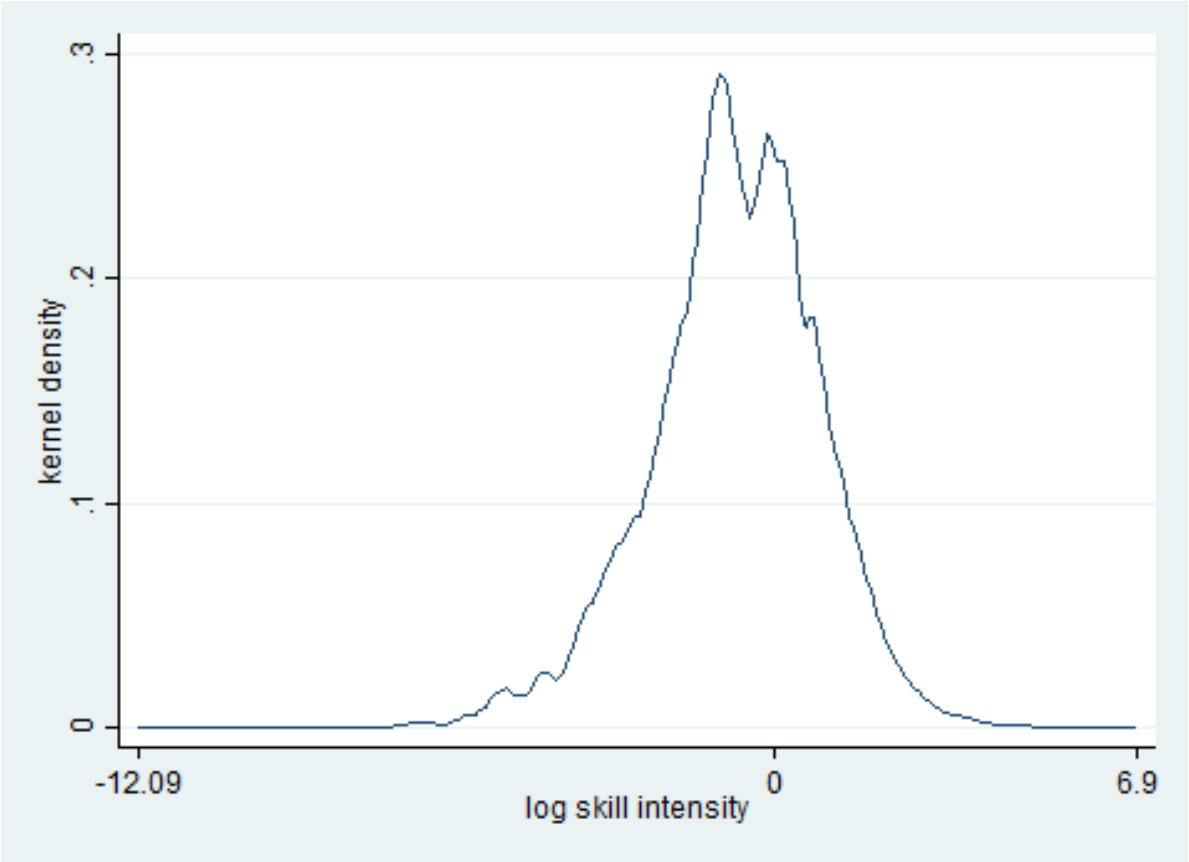


Figure : Distribution of log skill intensity within 4-digit manufacturing sectors. The figure plots the distribution of the firm-level log skill intensity, defined as the ratio of employment of non-blue collar workers to blue-collar production workers per firm.

Import share from labor-abundant countries and aggregate manufacturing skill intensity in France

Figure : Trend in imports from labor-abundant countries and trend in skill intensity in France (non-production/production workers in French manufacturing)

Firm-level skill intensity and imports from labor-abundant/skill-abundant countries

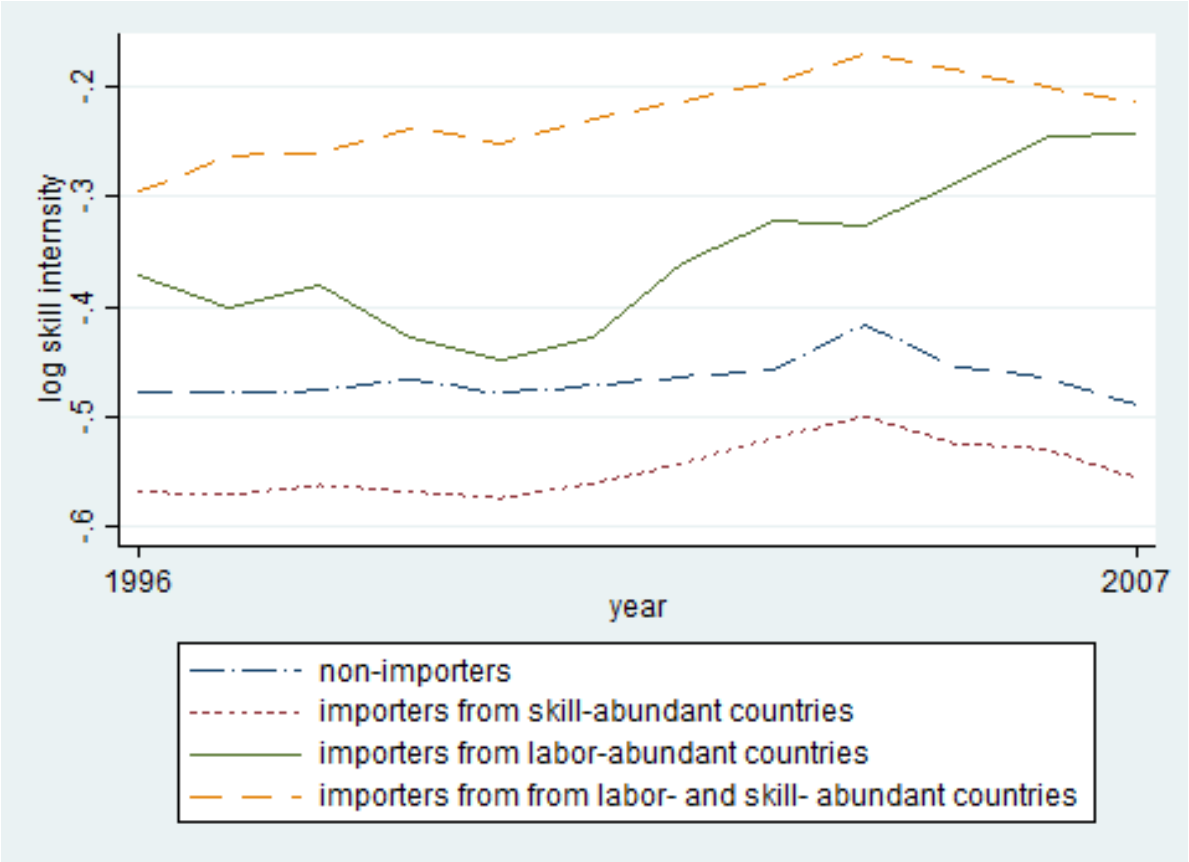


Figure : Skill intensity of domestic production for importers from labor-abundant countries/importers from skill-abundant countries/both sets of countries/non-importers

Theoretical approach

- We introduce 2 changes to the HO model to reconcile it with the evidence:
  1. Focus on firms' offshoring decisions (2 thirds of trade is in inputs).
  2. Add firm heterogeneity (Melitz, 2003).

- We develop a HO offshoring model with heterogeneous firms:
  - Countries differ in human capital abundance and inputs differ in skill intensity.
  - Human-capital-rich countries have a lower skill premium and thus a comparative advantage in skill-intensive inputs
    $\rightarrow$ i.e. computers are made cheaper in the US than in China.
  - Firms in any country can import intermediate inputs, subject to fixed costs.
    $\rightarrow$ Offshoring arises because of factor-price differences, but only productive-enough firms offshore due to the fixed costs.

Predictions

On **sourcing patterns**: TFP, origin the type of inputs imported

- The more productive a firm is, the more it will offshore inputs for which the cost-difference is low:

  $\rightarrow$ compare two firms offshoring to a labor-abundant country: the low-TFP firm will offshore the most labor-intensive input, the high-TFP firm will *also* offshore the more skill-intensive inputs.

  $\rightarrow$ same intuition applies to the offshoring locations for a given input.

On **domestic skill intensity**: origin of inputs

- Offshoring to a skill-abundant country involves relatively skill-intensive inputs
  $\rightarrow$ These inputs are no longer produce in-house: domestic skill intensity *decreases*.

- Offshoring to a labor-abundant country involves relatively labor-intensive inputs
  $\rightarrow$ These inputs are no longer produce in-house: domestic skill intensity *increases*.

Data

- Trade at firm-level (customs data): Firm-level imports and exports broken down by source country and HS6 product.
- "BRN" dataset. Administrative balance sheet dataset, exhaustive for medium and large firms to construct TFP (Levinsohn-Petrin).
- Skill structure at firm level. "DADS": occupational structure for all French firms with at least one employee. Provides number of jobs of each of seven categories (from managers to blue collars).

$$skill \quad intensity_{f,t} = \frac{non-blue-collar\ employment_{f,t}}{blue-collar\ employment_{f,t}}$$

- Skill intensity of product p: computed from US industry-level data (NBER):

$$skillint_p = non-blue\ collar\ employment_{p,US} / blue\ collar\ employment_{p,US}$$

- Skill intensity of imports from labor-abundant countries:

$$Import\ skill\ intensity_{ft} = \sum_p w_{pft} \times skillint_p$$

- w_{pft}: share of product p in imports of f from labor-abundant countries.

Estimating sample

- We consider countries with less (more) than 95% of French level of secondary schooling as labor abundant (skill abundant) (results are robust to alternative thresholds).
- Panel of 104,436 firms with data on TFP (3 factors – capital, skilled labor, unskilled labor –, value-added-based, Levinsohn-Petrin) , employment, imports by product and source country, capital/labor ratios and skill intensities of production for 1996-2007.
- 646,920 firm/year observations corresponding to 104,036 firms.
- 37,847 firms import at least once from skill-abundant countries and 25,296 import at least once from labor-abundant countries.
- average number of HS 6-digit products per firm sourced from skill-abundant (labor-abundant) countries: 10 (6).
- The vast majority of firms sources a given 6-digit product from a single location.

Testing predictions on sourcing patterns

- Prediction 1: more skill-abundant countries should have a comparative advantage in the production of more skill-intensive inputs and thus firms should import larger volumes.

$$\log(imports)_{f,p,c,t} = \beta_0 + \beta_1 \log(TFP)_{f,0} + \beta_2 skillint_p + \\ + \beta_3 skillint_p * sec.schooling_c + \beta_4 X_{c,t} + \epsilon_{f,p,c,t},$$

- $\log(imports)_{f,p,c,t}$ is the (log) import value of product p from country c by firm f in year t,
- $\log(TFP)_{f,0}$ is log TFP in the initial period of the sample (to mitigate endogeneity concerns),
- $skillint_p$ is the skill intensity of product p,
- $sec.schooling_c$ is the skill abundance (measured in terms of years of secondary schooling) of country c relative to France.
- The vector $X_{c,t}$ includes country and year fixed effects.

Testing predictions on sourcing patterns

- For importers from a specific labor-abundant (skill-abundant) country, the value of imports of relatively skill-intensive (labor-intensive) products from a given location should be larger for more productive firms. (Prediction 2, part (i)).

$$\log(imports)_{f,p,c,t} = \beta_0 + \beta_1 \log(TFP)_{f,0} + \beta_2 skillint_p + \\ + \beta_3 \log(TFP)_{f,0} * skillint_p + \beta_4 X_{f,c,t} + \epsilon_{f,p,c,t}$$

- The import value from relatively more skill-abundant (labor-abundant) locations should be larger for more productive firms offshoring to the set of labor-abundant (skill-abundant) countries (Prediction 3, part (i)):

$$\log(imports)_{f,p,c,t} = \beta_0 + \beta_1 \log(TFP)_{f,0} + \beta_2 sec.schooling_c + \\ + \beta_3 \log(TFP)_{f,0} * sec.schooling_c + \beta_4 X_{f,c,t} + \epsilon_{f,p,c,t}$$

- The vector $X_{c,t}$ includes firm controls, country fixed effects or gravity controls and year fixed effects.

Imports from labor-abundant/skill-abundant countries: HO comparative advantage; interactions of productivity with skill intensity/skill abundance

	dependent variable is log(imports)$_{f,p,c,t}$									
	from labor-abundant countries					from skill-abundant countries				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
log(TFP)$_{f,0}$	0.1512**	-0.1394	-0.1340	-0.1882***	-0.2346***	0.0816***	1.1615***	1.0307***	0.4144***	0.2116***
	(0.067)	(0.091)	(0.089)	(0.068)	(0.083)	(0.030)	(0.076)	(0.078)	(0.063)	(0.073)
skill intensity$_p$	-3.0102***	-5.2876***	-4.1948***			0.5789**	6.6495***	7.1983***		
	(0.292)	(1.288)	(1.241)			(0.232)	(0.914)	(0.891)		
skill intensity$_p$ x	**3.9804*** **					**0.3125***				
sec. schooling$_c$	(0.429)					(0.162)				
log(TFP)$_{f,0}$ x		**1.1276*** **	**0.7246** **				**-1.6220*** **	**-1.8383*** **		
skill intensity$_p$		(0.319)	(0.312)				(0.234)	(0.227)		
sec. schooling$_c$				-2.5594***	-1.6945**				0.6183***	0.6308***
				(0.678)	(0.769)				(0.178)	(0.187)
log(TFP)$_{f,0}$ x				**0.3765** **	**0.3802***				**-0.2512*** **	**-0.2401*** **
sec. schooling$_c$				(0.170)	(0.197)				(0.046)	(0.048)
log(employees)$_{f,t}$			0.0135		0.0048			0.0683***		0.1060***
			(0.030)		(0.029)			(0.014)		(0.014)
log(capital/labor)$_{f,t}$			0.1035***		0.1128***			0.1313***		0.1524***
			(0.032)		(0.033)			(0.013)		(0.014)
log(exports)$_{f,t}$			0.2395***		0.2260***			0.3517***		0.3567***
			(0.016)		(0.016)			(0.006)		(0.006)
Observations	666,208	666,208	666,208	683,598	605,100	3,661,016	3,672,029	3,672,029	3,709,549	3,707,103
Country FE	YES	YES	YES	NO	NO	YES	YES	YES	NO	NO
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Gravity Controls	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
R-squared	0.0314	0.0039	0.0291	0.0120	0.0388	0.0650	0.0184	0.0659	0.0032	0.0737

Testing predictions on domestic skill intensity of production

- Firms which import from labor-abundant (skill-abundant) countries are more skill intensive (labor intensive) in their domestic production compared to non-importers (Prediction 6).
- The skill intensity of domestic production should be increasing (decreasing) in import intensity from labor-abundant (skill-abundant) countries (Prediction 7).

$$\log(\textit{skillintensity})_{f,t} = \beta_0 + \beta_1 \textit{imports labor-abundant countries}_{f,t} + \\ + \beta_2 \textit{imports skill-abundant countries}_{f,t} + \beta_3 X_{f,t} + \epsilon_{f,t},$$

- $\textit{imports labor-abundant countries}_{f,t}$ is either a dummy for importing from labor-abundant countries or imports from labor-abundant countries/sales.
- $\textit{imports skill-abundant countries}_{f,t}$ is either a dummy for importing from skill-abundant countries or imports from skill-abundant countries/sales.
- $X_{f,t}$ includes 4-digit sector or firm FE, time FE, and firm-level controls.

Skill intensity of production and importing

	dependent variable is log(skill intensity)$_{ft}$							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
import status	**0.1996*** **	**0.2975*** **	**0.0388*** **	**0.0392*** **				
labor-abundant c.$_{f,t}$	(0.009)	(0.010)	(0.004)	(0.005)				
import status	**-0.0349*** **	**0.0708*** **	**-0.0124*** **	**0.0117** **				
skill-abundant c.$_{f,t}$	(0.006)	(0.007)	(0.003)	(0.005)				
imports/sales					**0.2500*** **	**0.3572*** **	**0.2152** **	**0.1703** **
labor-abundant c.$_{f,t}$					(0.096)	(0.101)	(0.099)	(0.083)
imports/sales					**-0.0086**	**-0.0109** **	**-0.0231**	**-0.0354** **
skill-abundant c.$_{f,t}$					(0.006)	(0.009)	(0.016)	(0.017)
log(TFP)$_{f,t-1}$		0.0965***		-0.0484***		-0.0493***		-0.0101
		(0.008)		(0.005)		(0.005)		(0.014)
log(employees)$_{f,t}$		-0.1550***		-0.1604***		-0.1603***		-0.2352***
		(0.003)		(0.006)		(0.006)		(0.024)
log(capital/labor)$_{f,t}$		0.0197***		-0.0163***		-0.0163***		-0.0490***
		(0.003)		(0.004)		(0.004)		(0.016)
export status$_{f,t}$		0.1002***		0.0159***				
		(0.006)		(0.004)				
log(exports)$_{f,t}$						0.0076***		0.0111***
						(0.001)		(0.004)
Observations	646,920	511,434	646,920	511,434	646,920	511,434	55,719	55,582
Firms	104,036	86,596	104,036	86,596	104,036	86,596	12,714	12,683
Sample	all	all	all	all	all	all	importers	importers
Firm FE	NO	NO	YES	YES	YES	YES	YES	YES
4-digit sector FE	YES	YES	NO	NO	NO	NO	NO	NO
Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
R-squared	0.2039	0.2317	0.0040	0.0113	0.0042	0.0117	0.0465	0.0615

Skill intensity of production and import skill intensity

	dependent variable is log(skill intensity)$_{f,t}$							
	Labor-abundant countries				Skill-abundant countries			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
import	**0.3791*** **	**0.2770*** **	**0.0340**	**0.0415**	**0.7428*** **	**0.6395*** **	**0.0157**	**0.0317**
skill intensity$_{f,t}$	(0.069)	(0.067)	(0.029)	(0.029)	(0.050)	(0.047)	(0.022)	(0.022)
log(TFP)$_{f,t-1}$		0.3088***		-0.0099		0.1737***		-0.0347***
		(0.023)		(0.015)		(0.015)		(0.008)
log(employees)$_{f,t}$		-0.1978***		-0.2489***		-0.1944***		-0.1966***
		(0.010)		(0.024)		(0.006)		(0.012)
log(capital/labor)$_{f,t}$		-0.0576***		-0.0600***		-0.0748***		-0.0429***
		(0.011)		(0.016)		(0.007)		(0.008)
log(imports)$_{f,t}$		0.0840***		0.0232***		0.0702***		0.0110***
		(0.006)		(0.006)		(0.003)		(0.002)
log(exports)$_{f,t}$		0.0408***		0.0059*		0.0375***		0.0061***
		(0.004)		(0.003)		(0.002)		(0.002)
Observations	55,528	55,528	55,528	55,333	152,281	151,635	152,281	151,635
Firms	13,343	13,297	13,343	13,297	28,433	28,328	28,433	28,328
Firm FE	NO	NO	YES	YES	NO	NO	YES	YES
4-digit sector FE	YES	YES	NO	YES	YES	NO	NO	NO
Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
R-squared	0.2644	0.3127	0.0419	0.0574	0.2655	0.3067	0.0151	0.0255

Conclusions

- We have developed a HO offshoring model with firm heterogeneity.
- Can explain intra-industry heterogeneity in firm-level skill intensity.
- Reduction in offshoring costs to labor-abundant countries leads to endogenous skill deepening.
- We provide empirical evidence on sourcing patterns and the impact of offshoring on firm-level skill demand in line with the model's prediction.
- The economic effects of offshoring on skill-upgrading are large.

Annex

Within-sector variation in skill intensity by import status

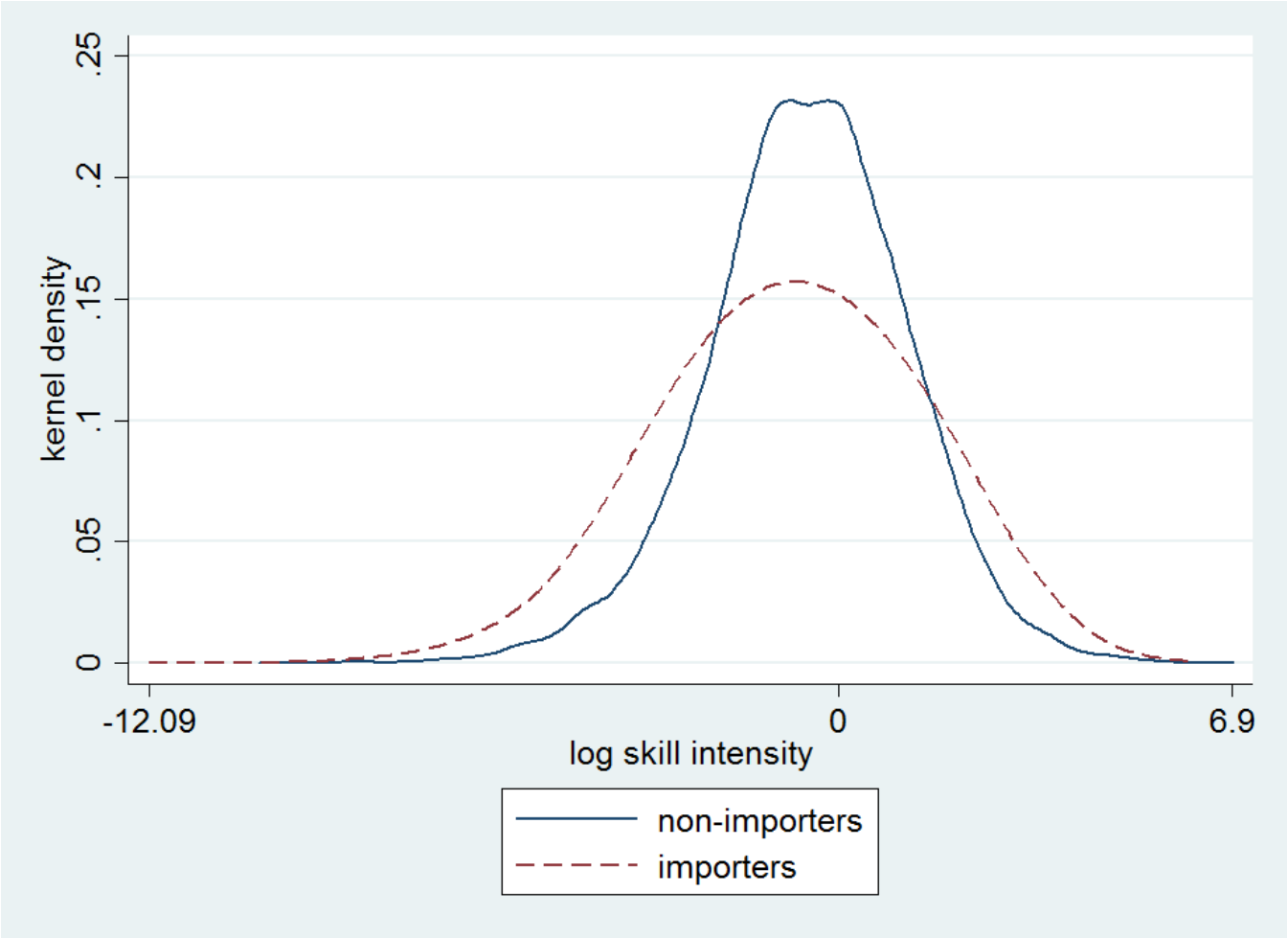


Figure : The figure plots the distribution of the firm-level log skill intensity, defined as the ratio of employment of non-blue collar workers to blue-collar production workers per firm, according to import status.

Import status and sorting by firm productivity

Table : TFP relative to sector-year average by import status

	Non-Importers		Importers labor-abundant c.		Importers skill-abundant c.		Importers both	
Year	Obs	Mean TFP	Obs	Mean TFP	Obs	Mean TFP	Obs	Mean TFP
1996	30,386	-0.036	690	-0.030	11,889	0.056	5,317	0.133
1997	30,815	-0.038	672	-0.041	12,471	0.055	5,783	0.142
1998	29,296	-0.036	758	-0.041	12,552	0.046	6,093	0.129
1999	29,670	-0.038	808	-0.052	12,353	0.050	6,402	0.129
2000	28,298	-0.035	833	-0.052	11,980	0.037	6,766	0.122
2001	27,810	-0.032	1,062	-0.030	10,502	0.040	6,769	0.110
2002	29,110	-0.031	1,210	-0.014	10,429	0.039	7,115	0.109
2003	28,040	-.0332	1,290	-0.007	10,051	0.040	7,163	0.111
2004	27,328	-0.035	1,254	-0.017	9,799	0.039	7,495	0.112
2005	26,866	-0.035	1,261	-0.020	9,407	0.038	7,878	0.107
2006	26,971	-0.036	1.436	-0.012	8,717	0.045	8,059	0.104
2007	23,658	-0.036	1,257	-0.021	7,503	0.045	7,818	0.096
All	338,248	-0.035	12,531	-0.025	127,653	0.045	82,658	0.116

Instrumental variables

- Comparative statics: a reduction in offshoring costs (or a positive Foreign supply shock) vis-à-vis labor-abundant countries for a *given set of products* leads to an increase in $z_n^-(\gamma)$ and $(1 - z_n^+(\gamma))$ (first stage); this impacts on domestic skill intensity (second stage).
- Supply shock instrument for firm-level imports:
  - w_{fpc0}: import share of firm f of product p from country c in the first period
  - X_{pct}: (log) export supply of product p by country c in year t (excluding France).

$$\widetilde{\text{imp. lab. abun.}}_{f,t,1} = \sum_{c \in I_{f,c,0}} \sum_{p \in I_{f,p,0}} w_{f,p,c,0} \times X_{p,c,t}$$

- 1-st stage IV regression:

$$\log(\text{imp. lab. abun.})_{f,t} = \alpha_0 + \alpha_1 \widetilde{\text{imp. lab. abund.}}_{f,t,1} + \alpha_2 \widetilde{\text{imp. skill abund.}}_{f,t,1} + \alpha_3 X_{f,t} + u_{f,t}$$

- $X_{f,t}$ includes firm and time FE (and firm-specific controls).
- 2-nd stage IV regression:

$$\log(\textit{skillintensity})_{f,t} = \beta_0 + \beta_1 \widehat{\text{imp. lab. abund.}}_{f,t} + \beta_2 \widehat{\text{imp. skill abund.}}_{f,t} + \beta_3 X_{f,t} + \epsilon_{f,t}$$

Skill intensity of production and importing – IV estimates

First Stage	Dep. var.: imports/sales labor-abundant c.$_{f,t}$		Dep. var.: imports/sales skill-abundant c.$_{f,t}$		Second Stage	Dep. var.: log(skill intensity)$_{f,t}$	
	(1)	(2)	(3)	(4)		(5)	(6)
IV Supply Shock labor-abundant c.$_{f,t}$	**0.0026*** **	**0.0023*** **	0.0027*	0.0023	**imports/sales labor-abundant c.$_{f,t}$**	**5.5135** **	**5.0714***
	(0.0008)	(0.0008)	(0.0016)	(0.0016)		(2.760)	(2.671)
IV Supply Shock skill-abundant c.$_{f,t}$	-0.0053*	-0.0050*	**0.0066** **	**0.0064** **	**imports/sales skill-abundant c.$_{f,t}$**	**-4.2816***	**-3.6571**
	(0.0029)	(0.0029)	(0.0027)	(0.0027)		(2.376)	(2.401)
log(TFP)$_{f,t-1}$		-0.0005		-0.0034	log(TFP)$_{f,t-1}$		-0.0193
		(0.0022)		(0.0027)			(0.020)
log(employees)$_{f,t}$		-0.0250***		-0.0163***	log(employees)$_{f,t}$		-0.1613*
		(0.0032)		(0.0058)			(0.087)
log(capital/labor)$_{f,t}$		-0.0028		0.0042	log(capital/labor)$_{f,t}$		-0.0186
		(0.0026)		(0.0028)			(0.026)
log(exports)$_{f,t}$		0.0084***		0.0094***	log(exports)$_{f,t}$		0.0044
		(0.0006)		(0.0008)			(0.034)
F-statistic (Angrist-Pischke)	15.32	13.28	11.57	9.26			
Observations	52,766	52,637	52,766	52,637		52,766	52,637
Firms	9,761	9,738	9,761	9,738		9,761	9,738
Sample	importers	importers	importers	importers		importers	importers
Firm FE	YES	YES	YES	YES		YES	YES
Time FE	YES	YES	YES	YES		YES	YES
Cluster	Firm	Firm	Firm	Firm		Firm	Firm

Economic magnitude of IV estimates

- Average firm-level skill intensity for importers from both sets of countries increased by 0.86 log points between 1996 and 2007
- Import intensity from labor-abundant countries increased from 0.053 to 0.07.
- Import intensity from skill-abundant countries stayed constant at 0.14.
- Predicted impact of changes in import intensity from labor-abundant countries: 0.93 log points (5.51*(0.07-0.053)=0.093).

- Firm-level skill intensity should increase in the skill intensity of imports from labor-abundant (skill-abundant) countries (Prediction 8).

$$\log(\textit{skillintensity})_{f,t} = \beta_0 + \beta_1 \textit{import skill intensity}_{f,t} + \beta_2 X_{f,t} + \epsilon_{f,t}$$

Skill intensity of production and import skill intensity: IV estimates

- Comparative statics: a reduction in offshoring costs vis-à-vis labor-abundant countries leads to an increase in $z_n^-(\gamma)$ and this increases the skill intensity of imports from labor-abundant countries (first stage). The increase in the skill intensity of imports increases the skill intensity of domestic production (second stage).
  - We regress the log value of imports of product i by firm f from country c on $\log(tariff_{pct})$ and firm-, product-, and country-fixed effects.

$$\log(imports)_{f,p,c,t} = \beta_0 + \beta_1 \log(tariff_{p,c,t}) + \delta_f + \delta_p + \delta_c + \epsilon_{f,p,c,t}.$$

  - Obtain predicted import values, explained by firm-, product-, country-means and tariffs and sum across countries to obtain a firm-product-time-specific weight:

$$\hat{w}_{f,p,t} = \frac{\sum_c \hat{import}_{f,p,c,t}}{\sum_p \sum_c \hat{import}_{f,p,c,t}}$$

  - Multiply these weights with product-specific skill intensities and sum over products to obtain the predicted skill content of imports.

$$\widetilde{skill\ intensity}_{f,t,1} = \sum_{p \in I_{f,p,t}} skillint_p \times \hat{w}_{f,p,t}.$$

- Supply shock instrument for the skill content of imports: similarly constructed.

dependent variable is log(skill intensity)$_{f,t}$				
	IV Estimates			
	(1)	(2)	(3)	(4)
import	**0.4184***	**0.4046****	**0.4801*****	**0.4731****
skill intensity$_{f,t}$	(0.185)	(0.183)	(0.187)	(0.185)
log(TFP)$_{f,t-1}$		-0.0158		-0.0159
		(0.016)		(0.016)
log(employees)$_{f,t}$		-0.2596***		-0.2605***
		(0.027)		(0.027)
log(capital/labor)$_{f,t}$		-0.0595***		-0.0596***
		(0.018)		(0.018)
log(imports)$_{f,t}$		0.0286***		0.0285***
		(0.006)		(0.006)
log(exports)$_{f,t}$		0.0060		0.0060
		(0.004)		(0.004)
Observations	46,063	45,903	46,015	45,857
Firms	8,854	8,824	8,847	8,818
Firm FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Cluster	Firm	Firm	Firm	Firm
R-squared	0.0390	0.0560	0.0394	0.0564
First-stage regression: dependent variable is skill content of imports$_{f,t}$				
tariff predicted skill intensity$_{f,t}$	0.3806***	0.3797***	0.3802***	0.793***
	(0.019)	(0.019)	(0.019)	(0.019)
supply-shock predicted skill intensity$_{f,t}$			0.0010***	0.0017***
			(0.0006)	(0.0005)
F-statistic	420.43	415.74	215.05	212.27
Hansen J statistic (p-value)	n.a.	n.a.	0.99	0.34

Model

- Multi-country model of offshoring with heterogeneous firms in a Heckscher-Ohlin environment.
- Firms must decide whether to offshore or not; which range of inputs to offshore; and to which countries to offshore.
- There are many countries, denoted with $n \in N$.
- Countries are endowed with exogenous amounts of two factors, skilled labor ("skills") H_n and unskilled labor ("labor") L_n, which are inelastically supplied.
- We label countries so that a higher n corresponds to a higher relative skill endowment H_n/L_n: $H_1/L_1 < H_2/L_2 < ... < H_N/L_N < 1$.

- There is one final-good industry.
- Consumers in country n derive utility from a Dixit-Stiglitz aggregate of final-good varieties:

$$C_n = \left[\int_{\omega \in \Omega_n} c_n(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}$$

- Each firm produces a different variety of the final good, over which it has monopoly power.
- Varieties of final goods are made by assembling a continuum of intermediate inputs:

$$q_n(\gamma) = \gamma \left[\int_0^1 x_n(z)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon-1}},$$

  where $1 < \varepsilon < \sigma$
- γ is a firm-specific productivity level, random and i.i.d. across firms within a country, and drawn from a distribution $G(\gamma)$ identical across countries.

Model

- Production of intermediate inputs for use in country n can potentially be outsourced to any country $n' \in N$ and are produced with skills and labor:

$$y_{n',n}(z) = \frac{Z(z)}{\tau} h_{n',n}(z)^{z} l_{n',n}(z)^{1-z},$$

- Skill intensities are increasing in z.
- $\tau \in \{1, \tau^{o}_{n',n}\}$: it takes value one if the firm produces the intermediate input in-house and value $\tau^{o}_{n',n} > 1$ if the input is sourced outside the firm.
- The variable outsourcing cost can be interpreted as a trade friction or as a cost or productivity disadvantage due to the outsourcing process.
- Outsourcing of each intermediate input is subject to a fixed cost f^{o} in terms of the final good.

Model

- Factor and intermediate-input markets are perfectly competitive.
- Varieties of final goods are freely traded.
- Since we assume no fixed cost of exporting, all firms operate in the domestic and in all foreign markets.
- For each intermediate z, firms located in country n decide whether and to which locations n' to offshore production.
- We assume that $w_{h1}/w_{l1} > w_{h2}/w_{l2} > ... > w_{hN}/w_{lN} \geq 1$ (holds in general equilibrium).

Minimum-cost sourcing in an N-country world

- Inputs are priced at marginal costs. The price of inputs produced in country n' for use by firms in country n is

$$p_{n',n}(z) = \tau^{o}_{n',n} w^{z}_{hn'} w^{1-z}_{ln'}$$

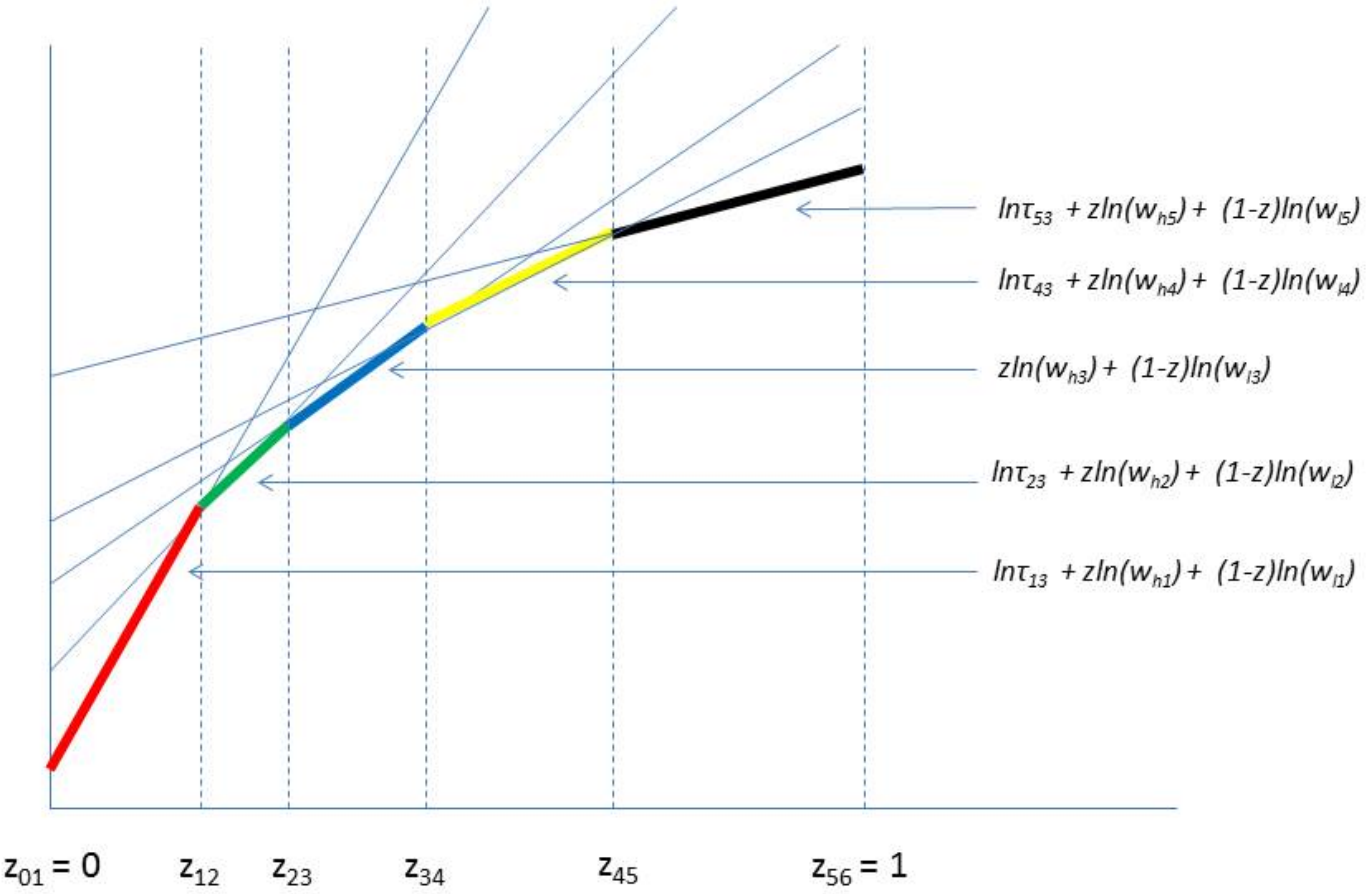
- The price of inputs produced in house is

$$p_{n,n}(z) = w^{z}_{hn} w^{1-z}_{ln}$$

- We plot the logarithms of these cost functions against z, (We set $N = 5$ and consider the offshoring decision from the perspective of a firm from country $n = 3$.)
- The lower envelope represents the lowest marginal costs at which country-n firms can obtain the different intermediate inputs.
- Cost reductions from offshoring are largest when inputs with extreme factor intensities are offshored to locations with extreme factor-price ratios.
- Cutoff conditions defining the minimum-cost sourcing decisions:

$$\tau^{o}_{n'-1,n} w^{z_{n'-1,n'}}_{hn'-1} w^{1-z_{n'-1,n'}}_{ln'-1} = \tau^{o}_{n',n} w^{z_{n'-1,n'}}_{hn'} w^{1-z_{n'-1,n'}}_{ln'} .$$

Minimum-cost sourcing decisions for country-3 firms



Offshoring decision with offshoring fixed costs

- In the absence of f^o, all firms in country n would import the range $[0, z_{n-1,n})$ from labor-abundant countries, of which $[0, z_{1,2})$ from country 1, $[z_{1,2}, z_{2,3})$ from country 2, etc.
- With $f^o > 0$ the offshoring decision depends on productivity γ.
- Let $z_n^-(\gamma)$ be the most skill-intensive input a country-n firm offshores to any country that is more labor abundant than n.
- Let $z_n^+(\gamma)$ be the most labor-intensive input offshored to any country that is more skill abundant than n.
- The range $\left(z_n^-(\gamma), z_n^+(\gamma)\right)$ is produced in-house by the country-n firm.
- The cost function of any given country-n firm depends on its offshoring pattern.

$$MC_n\left(\gamma, z_n^-, z_n^+\right) = \frac{1}{\gamma}\left[\sum_{n'=1}^{n^- -1}\int_{z_{n'-1,n'}}^{z_{n',n'+1}}\left(\tau^o_{n',n} w^z_{hn'} w^{1-z}_{ln'}\right)^{1-\varepsilon} dz + \int_{z_{n^- -1,n^-}}^{z_n^-}\left(\tau^o_{n^-,n} w^z_{hn^-} w^{1-z}_{ln^-}\right)^{1-\varepsilon} dz + \right.$$

$$\left. + \int_{z_n^-}^{z_n^+}\left(w^z_{hn} w^{1-z}_{ln}\right)^{1-\varepsilon} dz + \int_{z_n^+}^{z_{n^+,n^+ +1}}\left(\tau^o_{n^+,n} w^z_{hn^+} w^{1-z}_{ln^+}\right)^{1-\varepsilon} dz + \sum_{n'=n^+ +1}^{N}\int_{z_{n'-1,n'}}^{z_{n',n'+1}}\left(\tau^o_{n',n} w^z_{hn'} w^{1-z}_{ln'}\right)^{1-\varepsilon} dz.\right]^{\frac{1}{1-\varepsilon}}.$$

Offshoring decision

- Offshoring problem:

$$\max_{p,z_n^-,\left(1-z_n^+\right)} p_n q_n - \left[MC_n\left(\gamma, z_n^-, z_n^+\right)\right] q_3 - \left[z_n^- + \left(1-z_n^+\right)\right] Pf^o.$$

s.t. $q_n(\gamma) = \frac{p_n(\gamma)^{-\sigma}}{P^{1-\sigma}} E_W$

- Optimal pricing:

$$p_n\left(\gamma\right) = \frac{\sigma}{\sigma-1} MC_n\left(\gamma\right).$$

- First-order condition with respect to z_n^-:

$$\frac{\partial \Pi_n}{\partial z_n^-} = \frac{\partial \pi_n}{\partial z_n^-} - Pf^o = -\frac{\partial MC_n}{\partial z_n^-}\left(\frac{p_n^{-\sigma}}{P^{1-\sigma}} E_W\right) - Pf^o \leq 0,$$

with π_n increasing and concave in z_n^-, reflecting smaller cost gains from offshoring relatively more skill-intensive inputs to labor-abundant locations.

- First-order condition with respect to $\left(1-z_n^+\right)$:

$$\frac{\partial \Pi_n}{\partial\left(1-z_n^+\right)} = \frac{\partial \pi_n}{\partial\left(1-z_n^+\right)} - Pf^o = -\frac{\partial MC_n}{\partial\left(1-z_n^+\right)}\left(\frac{p_n^{-\sigma}}{P^{1-\sigma}} E_W\right) - Pf^o \leq 0,$$

with π_n increasing and concave in $1-z_n^+$, reflecting smaller cost gains from offshoring to relatively more labor-intensive inputs to skill-abundant locations.

- One can prove that $\partial z_n^-\left(\gamma\right)/\partial\gamma \geq 0$ and $\partial\left(1-z_n^+\left(\gamma\right)\right)/\partial\gamma \geq 0$ if $\sigma \geq \varepsilon > 1$

Predictions: offshoring patterns

- Conditional on offshoring, the log import value of a given intermediate z is given by:

$$\log(p_{n',n}(z)x_{n',n}(z)) = \Delta + (1-\varepsilon)\log(\tau^{o}_{n',n}) + (1-\varepsilon)\log(w_{ln'}) +$$
$$+(1-\varepsilon)z\log(w_{hn'}/w_{ln'}) + (\sigma-1)\log(\gamma) + (\varepsilon-\sigma)\log[\gamma MC_n\left(z_n^{-}(\gamma), z_n^{+}(\gamma)\right)]$$

- **Prediction 1**: *More skill-abundant countries have a comparative advantage in producing inputs with higher skill intensity. The import value of more skill-intensive inputs is thus larger when sourced from more skill-abundant countries.*
- $z_n^{-}(\gamma)$, increases in γ. Thus, for importers from a specific labor-abundant country n', the value of imports of relatively skill-intensive products will be larger for more productive firms, since import values are positive for $z \in [z_{n'-1,n'}, \min\{z_{n',n'+1}, z_n^{-}(\gamma)\}]$.
- **Prediction 2**: *(i) Holding constant a given labor-abundant (skill-abundant) source country, the import value of relatively skill-intensive (labor-intensive) inputs will be larger for more productive firms. (ii) In addition, more productive offshoring firms have more variation in the skill intensity of their imported goods from a given country.*

Predictions: offshoring patterns

- Consider two firms with productivity levels $\gamma_1 < \gamma_2$ sourcing from the set of labor-abundant countries. Import values from relatively more skill-abundant countries are larger for more productive firms, since they are positive for $z \in [0, \min\{z_{n',n'+1}, z_n^-(\gamma)\}]$.
- **Prediction 3**: *(i) The import value from relatively more skill-abundant (labor-abundant) locations will be larger for more productive firms offshoring to the set of labor-abundant (skill-abundant) countries. (ii) Moreover, more productive offshoring firms have more variation in the skill abundance of countries from which they import.*

Predictions: domestic skill intensity

- The skill intensity of domestic production of a firm located in country n is:

$$\frac{\int_{z_n^-(\gamma)}^{z_n^+(\gamma)} h_{n,n}(z)\,dz}{\int_{z_n^-(\gamma)}^{z_n^+(\gamma)} l_{n,n}(z)\,dz} = \frac{w_{ln}}{w_{hn}} \frac{\int_{z_n^-(\gamma)}^{z_n^+(\gamma)} z\left(w_{hn}^z w_{ln}^{1-z}\right)^{1-\varepsilon} dz}{\int_{z_n^-(\gamma)}^{z_n^+(\gamma)} (1-z)\left(w_{hn}^z w_{ln}^{1-z}\right)^{1-\varepsilon} dz} = \frac{w_{ln}}{w_{hn}}\Delta. \quad (1)$$

  with $\partial\Delta/\partial z_n^- > 0$ and $\partial\Delta/\partial\left(1-z_n^+\right) < 0$.

- **Prediction 4**: *Given heterogeneity in firm-level productivity γ, there is variation in skill intensity within sectors.*

- Given that $z_n^-(\gamma) = 0$ and $z_n^+(\gamma) = 1$ for all $\gamma < \gamma_n^o$:
- **Prediction 5**: *The variation in skill intensity of domestic production is larger across offshoring firms than across firms that source all inputs domestically.*

- Given that $\partial\Delta/\partial z_n^- > 0$ and $\partial\Delta/\partial\left(1-z_n^+\right) < 0$ it follows that:
- **Prediction 6**: *Offshoring to labor-abundant countries raises the skill intensity of domestic production, while offshoring to skill-abundant countries reduces it.*

Predictions: domestic skill intensity

- A country-n firm's import intensity from labor-abundant countries is given by

$$\text{Imports/variable costs}_{f,t} = \frac{\left[\sum_{n'=1}^{n^- - 1} \int_{z_{n'-1,n}}^{z_{n',n'+1}} p_{n',n}^{1-\varepsilon}(z)\,dz + \int_{z_{n^- - 1,n^-}}^{z_n^-(\gamma)} p_{n^-,n}^{1-\varepsilon}(z)\,dz\right]}{\gamma^{1-\varepsilon} MC_n^{1-\varepsilon}},$$

  which increases in $z_n^-(\gamma)$. Similarly, the import intensity from skill-abundant countries increases in $1 - z_n^+(\gamma)$. The skill intensity of domestic production increases in $z_n^-(\gamma)$ and decreases in $1 - z_n^+(\gamma)$. It thus follows that:

- **Prediction 7** *The skill-intensity of domestic production is increasing (decreasing) in import intensity from labor-abundant (skill-abundant) countries.*

- Consider the import-share-weighted skill intensity of imports from labor-abundant (skill-abundant) countries. One can show:

- **Prediction 8**: *The skill intensity of domestic production increases in the skill intensity of imports (from labor- and skill-abundant countries).*

Extra predictions on sourcing patterns: dispersion

- More productive importers should have a larger variation in the skill intensity of imported products from a given source country (Prediction 2, part (ii)).
- We compute the firm-level standard deviation of skill intensity of imports by source country:

$$dispersion_{f,c} = \beta_0 + \beta_1 \log(TFP)_f + \beta_2 X_{f,c} + \epsilon_{f,c}.$$

- More productive firms should have more variation in the skill abundance of their source countries (Prediction 3, part (ii)).
- We compute the firm-level standard deviation of skill abundance of source countries:

$$dispersion_f = \beta_0 + \beta_1 \log(TFP)_f + \beta_2 X_f + \epsilon_f.$$

Dispersion of skill intensity of imported products/skill abundance of sourcing locations and productivity

	dependent variable is standard deviation of							
	product skill-intensity$_{f,c}$ of imports from labor-abundant countries		country skill-abundance$_f$		product skill-intensity$_{f,c}$ of imports from skill-abundant countries		country skill-abundance$_f$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log(TFP)$_f$	**0.0179*** **	**0.0111*** **	**0.0407*** **	**0.0444*** **	**0.0083*** **	**0.0051*** **	**0.0313*** **	**0.0178** **
	(0.000)	(0.001)	(0.011)	(0.011)	(0.000)	(0.000)	(0.007)	(0.007)
log(employees)$_f$		0.0034***		0.0012		0.0035***		-0.0196***
		(0.000)		(0.005)		(0.000)		(0.003)
log(capital/labor)$_f$		-0.0012***		-0.0088		0.0027***		-0.0076**
		(0.000)		(0.006)		(0.000)		(0.004)
log(exports)$_f$		0.0025***		-0.0135***		0.0005***		-0.0147***
		(0.000)		(0.003)		(0.000)		(0.002)
log(# products)$_{f,c}$	0.0125***	0.0100***			0.0114***	0.0083***		
	(0.000)	(0.001)			(0.000)	(0.001)		
log(# countries)$_f$			0.2628***	0.2763***			0.2296***	0.2703***
			(0.007)	(0.008)			(0.007)	(0.009)
Observations	48,469	48,469	14,573	14,573	149,719	149,719	31,218	31,218
R-squared	0.0794	0.1000	0.0827	0.0839	0.0763	0.0864	0.0575	0.0613
Country FE	NO	YES	NO	NO	NO	YES	NO	NO
Robust	YES	YES	YES	YES	YES	YES	YES	YES

Extra predictions on sourcing patterns: complementarities

- **Prediction 9**: *Holding firm-level productivity constant, offshoring firms sourcing from a more labor-abundant set of labor-abundant countries import a larger volume from any given source country. Similarly, holding firm-level productivity constant, offshoring firms sourcing from a more skill-abundant set of skill-abundant countries import a larger volume from any given source country.*

$$\log(imports)_{f,p,c,t} = \beta_0 + \beta_1 \log(TFP)_{f,0} + \beta_2 skillint_p + \\ + \beta_3 skillint\ other\ products_{f,p,t} + \beta_5 X_{f,c,t} + \epsilon_{f,p,c,t},$$

- **Prediction 10**: *Holding firm-level productivity constant, offshoring firms importing a more labor-intensive set of labor-intensive products import a larger volume from any given source country. Similarly, holding firm-level productivity constant, offshoring firms importing a more skill-intensive set of skill-intensive products import a larger volume from any given source country.*

$$\log(imports)_{f,p,c,t} = \beta_0 + \beta_1 \log(TFP)_{f,0} + \beta_2 sec.schooling_c + \\ + \beta_3 sec.\ schooling\ other\ countries_{f,c,t} + \beta_5 X_{f,c,t} + \epsilon_{f,p,c,t},$$

Complementarities in sourcing decisions

	dependent variable is log(imports)$_{f,p,c,t}$							
	from labor-abundant countries				from skill-abundant countries			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
skill intensity other products$_{f,p,t}$	**-2.2522*** **	**-2.9925*** **			**2.6716*** **	**1.9826*** **		
	(0.356)	(0.363)			(0.246)	(0.240)		
sec. schooling other countries$_{f,c,t}$			**-1.0414*** **	**-1.2502*** **			**0.3010*** **	**0.2577*** **
			(0.141)	(0.142)			(0.081)	(0.079)
skill intensity$_{p}$	-0.0035	-0.3986**			-0.0201	-0.1417		
	(0.239)	(0.193)			(0.113)	(0.096)		
sec. schooling$_{c}$			-1.0610***	-0.1442			-0.9251***	-1.1082***
			(0.120)	(0.106)			(0.059)	(0.256)
log(TFP)$_{f,0}$	0.1659*	0.0499	0.0289	-0.0619	0.6186***	0.4135***	0.5800***	0.4506***
	(0.088)	(0.088)	(0.082)	(0.077)	(0.045)	(0.044)	(0.055)	(0.054)
log(employees)$_{f,t}$		0.0864***		0.0784**		0.1729***		0.0877***
		(0.029)		(0.037)		(0.015)		(0.018)
log(capital/labor)$_{f,t}$		0.0501		0.0522		0.1098***		0.1451***
		(0.056)		(0.055)		(0.019)		(0.021)
log(exports)$_{f,t}$		0.2423***		0.2478***		0.3802***		0.3801***
		(0.017)		(0.023)		(0.009)		(0.010)
# products$_{f,t}$	-0.0036*	-0.0051**			-0.0022***	-0.0048***		
	(0.002)	(0.002)			(0.000)	(0.000)		
# countries$_{f,t}$			-0.0160*	-0.0300***			0.0323***	-0.0372***
			(0.008)	(0.009)			(0.010)	(0.012)
Observations	430,635	430,635	427,815	375,152	1,327,313	1,327,313	1,250,216	1,246,583
Country FE	YES	YES	NO	NO	YES	YES	NO	NO
Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Cluster	Firm	Firm	Firm	Firm	Firm	Firm	Firm	Firm
R-squared	0.0118	0.0415	0.0176	0.0477	0.0961	0.0961	0.0234	0.0802

Summary statistics

Variable	Mean	Std. Dev.	5th Pct.	95th Pct.	Obs.
Skill ratio	1.18	4.50	0.14	3.50	646,920
Employees	53.51	336.58	3.00	174.00	646,920
(log) TFP	3.83	0.46	3.05	4.56	646,920
(log) Capital/labor	3.25	0.99	1.52	4.83	646,920
Imports (in 1000 euros)	1,908	24,403	0.0	4,047	646,920
Exports (in 1000 euros)	1,375	26,606	0.0	3,030	646,920
Number of products imported (all origins)	5.36	16.72	0.00	29.00	646,920
Number of products imported from skill-abundant countries	10.07	19.02	1.00	39.00	182,239
Number of products imported from labor-abundant countries	6.11	11.59	1.00	24.00	96,039
Number of countries per firm-product (all origins)	1.74	1.11	1.00	3.74	224,039
Number of countries per firm-product (skill-abundant countries)	1.21	0.39	1.00	2.00	182,239
Number of countries per firm-product (labor-abundant countries)	1.35	0.96	1.00	2.61	96,039

Related literature

- Trade and skill upgrading:
  - Heterogeneous firms and exogenous skill intensity: Burstein and Vogel (2016)
  - Assortative matching: Helpman et al. (2010,2015)
  - Exporting and skill upgrading: Verhoogen (2011), Bustos (2012)
- Offshoring and skill demand (theory):
  - Homogeneous-firm HO model: Feenstra and Hanson (1997)
  - Complementarities between domestic and foreign tasks: Grossman and Rossi-Hansberg (2008)
- Offshoring and skill demand (empirics):
  - Wages of Danish/French workers: Hummels et al. (2013), Carluccio et al. (2015)
- Multi-country sourcing models:
  - Antras et al. (2014)