Offshoring under Uncertainty

Wilhelm Kohler(*) and Bohdan Kukharskyy(*)
* University of Tübingen

Research Seminar

University of Graz, June 27, 2017

Introduction

- Offshoring (**O**): obtaining inputs (slices of value added, tasks) from cheaper (low-wage) "offshore" locations
- Does uncertainty (**U**) matter? – "No-brainer": YES
- Yet: **U** appears less than prominently in the economics literature on **O**
- Research question must be more specific:
  - What kind of **U** (supply, demand, ...)?
  - **O**-decision margin (offshoring at all, type of input, where to source, ...)?
  - Exogenous variation, shock (trade policy, labor market policy, ...)?
  - Outcome that we are interested in (wage, employment, volatility, welfare, ...)?

Introduction

- Stylized facts: **O** differently prevalent
  - across firms
  - across industries
  - across possible offshore countries (**O**Cs)
- What drives this variation, in view of **U**?
  - **O**Cs differently risky (**O** as a source of **U**)?
  - **O**Cs differently flexible environments to deal with **U**?
  - Industries differently exposed to **U**?
  - Firms' ability to absorb the cost of flexibility?
- This paper: theoretical model plus empirical analysis of this

Existing literature

- [?], [?]: focusing on **final goods**, **U in productivity**, source of countries' *comparative advantage*: complete rigidity vs. complete flexibility to adjust (country characteristic) – degree of risk, volatility (industry characteristic)
- [?] and [?]: focusing on **O**, **U in demand** without costly adjustment (or rigidity), US-Mexico (maquiladora industries), consequence of **O** for *volatility of employment*

Existing literature

- [**?**]: focusing on **O with incomplete contracts**, **U in demand** $\Longrightarrow$ strategy of generating revenue: domestic sales, exports with final assembly (ortsourcing to independent assembler vs. integrated assembler)
- [**?**]: focusing on **O and demand U** with adjustment through intertemporal optimization, **O** $\Longrightarrow$ degree of volatility, increase in degree of uncertainty $\Longrightarrow$ **O**

A baseline model: demand uncertainty

- Drawing on [?] and [?], but assuming complete contracts and introducing demand **U**
- Several industries in the background, singling out any one for detailed analysis
- Final good (x) produced using two inputs: h (**H**eadquarter service, no **O**) and m (**M**anufacturing components, **O**):

$$x = \theta \left(\frac{h}{\eta} \right)^{\eta} \left(\frac{m}{1-\eta} \right)^{1-\eta}, \tag{1}$$

  - θ: firm's productivity
  - $\eta \in (0, 1)$: headquarter intensity
  - h and m produced using only labor

A baseline model: demand uncertainty

- **O** of m: $z = o$ (offshore), d (domestic)
  - Fixed cost: $F_d < F_o$
  - **O**-cost ("iceberg") $\tau > 1$
- Market structure for final good: monopolistic competition

$$R = x^{\frac{\sigma-1}{\sigma}} A^{\frac{1}{\sigma}}, \tag{2}$$

- $A := \beta E P^{\sigma-1}$ is a demand shifter capturing **U**:
  - $A = A_G$ (good state) with probability $g \in (0,1)$, $A_B < A_G$ with probability $1-g$
  - Index for "state of nature": $s \in \{G, B\}$
  - s verifiable by court $\Longrightarrow$ contingent contracts
  - Same type and degree of **U** for all firms, but $v := (A_G - A_B)/A_G$ different across industries

A baseline model: types of contracts

- Flexible (f) sourcing contract or m:
  - Entered by H and M before s is revealed,
  - specifying **state-contingent quantity** m^f_{zs} determined by H, to be delivered by M after s is revealed (verifiably!)
  - H liable to compensate M for cost of adjustment in lump-sum manner – additional fixed cost F_{az}
  - Assumption: $F_{ad} < F_{ao}$ (more flexible domestic labor market)
- Rigid (r) sourcing contract:
  - Entered by H and M before s is revealed,
  - specifying **fixed quantity** m^r_z determined by H, to be delivered by M after s is revealed, but independent on state of nature
  - Flexibility of adjusting to s is partially lost, but advantage: no additional fixed cost for flexibility
- In either case: $h^{\cdot}_{zs}$ state-dependent

A baseline model: demand uncertainty

- Large pool of suppliers (in d as well as o) with *zero outside option*

$\Longrightarrow$ Compensation of M per unit of m:

$$p_z = \begin{cases} \ell & \text{if } z = d \\ \tau w \ell & \text{if } z = o \end{cases} \tag{3}$$

$\Longrightarrow$ For flexible contracts: plus lump-sum compensation F_{az} with $F_{ao} > F_{ad} = 0$

A baseline model: demand uncertainty

- Sequencing in time t
  - t_1 H decides about
    - location of sourcing, $z \in \{d, o\}$, incurring F_z
    - and type of contract, r or $f \Longrightarrow m_z^r$ or m_{zs}^f, F_{az}
  - t_2 Shock occurs $\Longrightarrow s \in \{G, B\}$
  - t_3 Contract fulfilled, and H decides about $h \Longrightarrow h_{zs}^r$ or h_{zs}^f, depending on known "state of nature"
- Solution concept: backward induction

Domestic sourcing $(z = d)$ – **flexible** contract

- Optimization problem collapsing to single stage

$$\max_{h,m} R_s - \ell m - h - F_d, \tag{4}$$

- leading to profit maximizing input quantities

$$h^f_{ds} = \frac{\eta(\sigma-1)R^f_{ds}}{\sigma}, \quad m^f_{ds} = \frac{(1-\eta)(\sigma-1)R^f_{ds}}{\ell\sigma}, \tag{5}$$

$$R^f_{ds} := \sigma\ell^{-\gamma}\Theta\Gamma A_s, \quad \Theta := \theta^{\sigma-1}, \tag{6}$$

$$\Gamma := \frac{(\sigma-1)^{\sigma-1}}{\sigma^\sigma} > 0, \quad \gamma := (1-\eta)(\sigma-1) > 0 \tag{7}$$

- and maximum profit (value function)

$$\pi^f_{ds} = \ell^{-\gamma}\Theta\Gamma A_s - F_d, \tag{8}$$

$$\text{exp. v.} \quad \mathbf{E}(\pi^f_d) = \ell^{-\gamma}\Theta\Gamma(gA_G + (1-g)A_B) - F_d. \tag{9}$$

Domestic sourcing $(z = d)$ – **rigid** contract

- h determined in t_3, conditional on m_d^r (chosen in t_1), from

$$\max_h R_s - h - F_d, \tag{10}$$

- leading to

$$\begin{aligned} h_{ds}^r &= \frac{\eta(\sigma-1)R_{ds}^r}{\sigma} \\ R_{ds}^r &:= \left(\theta\left(\frac{\sigma-1}{\sigma}\right)^{\eta}\left(\frac{m_d^r}{1-\eta}\right)^{1-\eta}\right)^{\frac{\sigma-1}{\sigma(1-\eta)+\eta}} A_s^{\frac{1}{\sigma(1-\eta)+\eta}} \end{aligned} \tag{11}$$

Net rev. for H: $R_{dsn}^r := R_{ds}^r - h_{ds}^r = \frac{\sigma(1-\eta)+\eta}{\sigma} R_{ds}^r$.

Domestic sourcing $(z = d)$ – **rigid** contract

- In t_1:

$$\max_m E(R^r_{dsn}) - \ell m - F_d \qquad (12)$$

$$E(R^r_{dsn}) := \frac{\sigma(1-\eta)+\eta}{\sigma}(gR^r_{dG} + (1-g)R^r_{dB}),$$

- leading to

$$m^r_d = \frac{(1-\eta)(\sigma-1)E(R^r_{dsn})}{\ell(\sigma(1-\eta)+\eta)} \qquad (13)$$

$$E(R^r_{dsn}) = (\sigma(1-\eta)+\eta)\ell^{-\gamma}\Theta\Gamma \times \left(gA_G^{\frac{1}{\sigma(1-\eta)+\eta}} + (1-g)A_B^{\frac{1}{\sigma(1-\eta)+\eta}}\right)^{\sigma(1-\eta)+\eta}$$

Domestic sourcing $(z = d)$ – **rigid** contract

- and maximum expected profits

$$\mathbf{E}(\pi_d^r) = \ell^{-\gamma}\Theta\Gamma\left(gA_G^{\frac{1}{\sigma(1-\eta)+\eta}} + (1-g)A_B^{\frac{1}{\sigma(1-\eta)+\eta}}\right)^{\sigma(1-\eta)+\eta} - F_d. \tag{14}$$

- **Optimal contract:** flexible iff $E(\pi_d^f) > E(\pi_d^r) \iff$

$$J := \frac{gA_G + (1-g)A_B}{\left(gA_G^{\frac{1}{\sigma(1-\eta)+\eta}} + (1-g)A_B^{\frac{1}{\sigma(1-\eta)+\eta}}\right)^{\sigma(1-\eta)+\eta}} > 1 \tag{15}$$

Domestic sourcing $(z = d)$ – **optimal** contract

Lemma

(i) $J > 1$ *for all* $A_G > A_B$ *and* $g \in (0, 1)$*, i.e., for* $v > 0$*. (ii)* J *increases in* v*.*

J: degree of *operating*-profit-advantage from flexibility

$F_{ad} = 0$

$\Longrightarrow$ **all firms sourcing domestically prefer flexible contracts**

Offshoring

- **O** - flexible contract

$$\mathbf{E}(\pi_o^f) = \omega\ell^{-\gamma}\Theta\Gamma(gA_G + (1-g)A_B) - F_o - F_{ao}. \quad (16)$$

- **O** - rigid contract:

$$\begin{aligned} \mathbf{E}(\pi_o^r) &= \omega\ell^{-\gamma}\Theta\Gamma\left(gA_G^{\frac{1}{\sigma(1-\eta)+\eta}} + (1-g)A_B^{\frac{1}{\sigma(1-\eta)+\eta}}\right)^{\sigma(1-\eta)+\eta} \\ &\quad -F_o. \end{aligned} \quad (17)$$

Firm-sorting

- Additional assumptions:

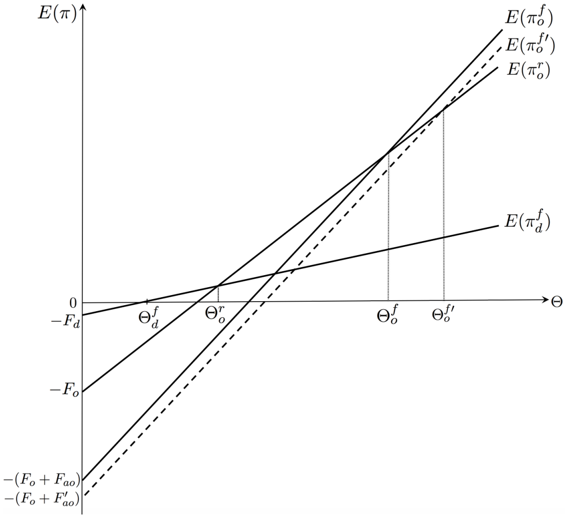
  (i) $\omega > J$; (ii) $\frac{F_o}{F_d} > \frac{\omega}{J}$; (iii) $\frac{F_{ao}}{F_o - F_d} > \frac{\omega(J-1)}{\omega - J}$

- **Productivity-based sorting** of firms into sourcing modes

- Define $\tilde{m}_z^f := g m_{zG}^f + (1-g) m_{zB}^f$, with g being the share of firms in good state (law of large numbers)

- Define $\theta_d^f = (\Theta_d^f)^{\frac{1}{\sigma-1}}$, $\theta_o^r = (\Theta_o^r)^{\frac{1}{\sigma-1}}$, and $\theta_o^f = (\Theta_o^f)^{\frac{1}{\sigma-1}}$

Firm-sorting



Testable predictions

- Define share of offshoring

$$Y := \frac{\int_{\theta_o^r}^{\theta_o^f} p_o m_o^r \,\mathsf{d}\Phi(\theta) + \int_{\theta_o^f}^{\infty} p_o \tilde{m}_o^f \,\mathsf{d}\Phi(\theta)}{\int_{\theta_d^f}^{\theta_o^r} p_d \tilde{m}_d^f \,\mathsf{d}\Phi(\theta) + \int_{\theta_o^r}^{\theta_o^f} p_o m_o^r \,\mathsf{d}\Phi(\theta) + \int_{\theta_o^f}^{\infty} p_o \tilde{m}_o^f \,\mathsf{d}\Phi(\theta)},$$

- Firm productivities Pareto-distributed

$$\Phi(\theta) = 1 - \left(\frac{\theta_{\mathsf{min}}}{\theta}\right)^{\kappa}, \quad \theta \geq \theta_{\mathsf{min}} > 0, \quad \kappa > \sigma - 1,$$

Testable predictions

Proposition

Increase in the rigidity of a foreign country's labor market $F_{ao} \longrightarrow F'_{ao} > F_{ao}$ *leads to lower offshoring intensity in any given industry, i.e.,* $\frac{\partial Y}{\partial F_{ao}} < 0$.

Proposition

The negative effect of foreign labor market rigidity on the offshoring intensity is more pronounced for a an industry with higher volatility, i.e., $\frac{\partial^2 Y}{\partial F_{ao} \partial v} < 0$.

Alternative model: supply uncertainty

- States of nature:
  - good $\longrightarrow \ell = \ell_G$ with probability $g \in (0,1)$
  - bad $\longrightarrow \ell = \ell_B > \ell_G$
  - identically for domestic and foreign suppliers
- Contracts as above with

$$p_z^r = \begin{cases} g\ell_G + (1-g)\ell_B & \text{if } z = d \\ \tau w[g\ell_G + (1-g)\ell_B] & \text{if } z = o \end{cases} \tag{18}$$

$$p_{zs}^f = \begin{cases} \ell_s & \text{if } z = d \\ \tau w \ell_s & \text{if } z = o \end{cases} \tag{19}$$

Alternative model: supply uncertainty

- Rigid contract now completely removes all uncertainty
  $\Longrightarrow h_z^r$ in t_3 not state-specific
- Maximum profits driving H-behavior regarding z and f, r:

$$\begin{aligned}
\mathbf{E}(\pi_d^f) &= [g\ell_G^{-\gamma} + (1-g)\ell_B^{-\gamma}]\Theta\Gamma A - F_d && (20) \\
\pi_d^r &= [g\ell_G + (1-g)\ell_B]^{-\gamma}\Theta\Gamma A - F_d && (21) \\
\mathbf{E}(\pi_o^f) &= \omega[g\ell_G^{-\gamma} + (1-g)\ell_B^{-\gamma}]\Theta\Gamma A - F_o - F_{ao} && (22) \\
\pi_o^r &= \omega[g\ell_G + (1-g)\ell_B]^{-\gamma}\Theta\Gamma A - F_o. && (23)
\end{aligned}$$

- J now appearing as

$$J := \frac{g\ell_G^{-\gamma} + (1-g)\ell_B^{-\gamma}}{[g\ell_G + (1-g)\ell_B]^{-\gamma}}, \qquad (24)$$

- Propositions analogous to 1 and 2 above

Implementation - main idea and data

- Main idea: testing above propositions
  - using cross-**O**-country (l) variation of labor market rigidity (proxying F_{al})
  - using cross-industry (i) variation of degree of uncertainty (proxying v_i)
- Data:
  - US-data for Y_{il}
  - US-data for v_i
  - and World-Bank data for F_{al}

Implementation - Proposition 1

Controling for other country characteristics, Y_{il} should decrease as F_{al} increases

$$\ln Y_{lit} = \alpha \, \textit{rigidity}_{lt} + \gamma \boldsymbol{X}_{lt} + \delta_l + \mu_i + \rho_t + \varepsilon_{lit}, \qquad (25)$$

- $\boldsymbol{X}_{lt}$ are time-varying country-level controls
- δ_l and μ_i time-invariant fixed effects
- ρ_t is time-specific fixed-effect

Implementation - Proposition 2

This rigidity-effect should be different across industries - stronger with higher volatility

$$\ln Y_{lit} = \beta \, \textit{rigidity}_{lt} \times \textit{volatility}_i + \zeta \boldsymbol{X}_{lt} \times \boldsymbol{\chi}_i + \boldsymbol{\varphi} + \varepsilon_{lit}, \qquad (26)$$

- Specification 1: $\boldsymbol{\varphi}$ is country×year FE plus indusrty FE
- Specification 2: $\boldsymbol{\varphi}$ is country×industry FE plus year FE

Econometric problem: "zeros in the data"

- Underlying (latent) dependent variable: difference in maximum profits

$$L := \mathbf{E}(\pi^{\cdot}_{o}) - \mathbf{E}(\pi^{\cdot}_{d}) + \text{ error term} \tag{27}$$

Suppose $Y = L$, if L this is positive, but $Y = 0$ if this is negative

- Problem: $E(Y|Y > 0) \neq E(L)$, but

$$E(L) + \sigma \times \text{ inverse Mills ratio} \tag{28}$$

- This suggests including the **inverse Mills ratio** in the model for $E(L)$; requires estimation of an equation **explaining the selection**, i.e., $\Pr[Y > 0]$ – e.g., via Probit

Data

- Y_{ilt}: $d =$ US, 253 US manufacturing sectors, $o =$ 232 countries, $t =$ 2000-2011, from [**?**], US-Census plus NBER data base
- F_{alt}: labor market rigidity from World Bank's "Doing Business Data Bas"; [**?**]
- v_i: based on growth rate of firm sales within industry i; [**?**], [**?**]
- $\mathbf{X}_{lt}$: see paper

Results proposition 1

Table 1: U.S. offshoring intensity and foreign labor market rigidity (baseline results).

	Dependent variable: ln(U.S. offshoring intensity)$_{lit}$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$rigidity_{lt}$	-0.407**	-0.391**	-0.415**	-0.451**	-0.496**	-0.492**	-0.572**
	(0.183)	(0.186)	(0.186)	(0.203)	(0.233)	(0.239)	(0.223)
$\ln GDP_{lt}$		-0.001	-0.377	-0.727	-1.052	-1.047	-1.135
		(0.551)	(0.593)	(0.681)	(0.749)	(0.752)	(0.772)
$\ln(GDPpc)_{lt}$		0.462	0.865	1.323*	1.906**	1.926**	1.996**
		(0.521)	(0.580)	(0.672)	(0.747)	(0.750)	(0.785)
$rule_{lt}$			-0.030	-0.003	-0.036	-0.043	-0.291*
			(0.130)	(0.128)	(0.142)	(0.145)	(0.157)
$\ln(credit/GDP)_{lt}$			-0.105	-0.126	-0.196*	-0.198	-0.255**
			(0.095)	(0.101)	(0.112)	(0.120)	(0.124)
$\ln(K/L)_{lt}$				0.038	0.098	0.110	0.017
				(0.192)	(0.212)	(0.225)	(0.217)
H_{lt}				0.483	0.384	0.311	0.108
				(0.759)	(0.805)	(0.830)	(0.815)
Country, industry, year FE	yes	yes	yes	yes	yes	yes	yes
Sample restriction (Wright)	no	no	no	no	yes	yes	yes
Sample restriction (NT)	no	no	no	no	no	yes	yes
Sample selection correction	no	no	no	no	no	no	yes
Observations	105,938	102,796	97,406	92,697	66,214	62,493	62,225
R-squared	0.604	0.604	0.601	0.590	0.619	0.617	0.616

Note: The table reports estimates of equation (32) with ln(U.S. offshoring intensity)$_{lit}$ as a dependent variable. All specifications include country, industry, and year fixed effects. Standard errors are clustered at the country level and presented in parentheses. *, **, *** indicate significance at 1, 5, 10%-level, respectively.

Results proposition 1

Table 2: U.S. offshoring intensity and labor market rigidity (robustness).

	Dependent variable: ln(U.S. offshoring intensity)$_{lit}$					
	(1)	(2)	(3)	(4)	(5)	(6)
$rigidity_{lt}$	-0.571**	-0.579***	-0.572**	-0.555**	-0.572**	-0.552**
	(0.230)	(0.218)	(0.223)	(0.228)	(0.222)	(0.235)
$corruption_{lt}$	-0.007					-0.066
	(0.109)					(0.119)
$effectiveness_{lt}$		0.176**				0.184**
		(0.086)				(0.087)
$stability_{lt}$			0.001			-0.018
			(0.057)			(0.060)
$quality_{lt}$				0.089		0.063
				(0.119)		(0.129)
$voice_{lt}$					0.004	0.012
					(0.091)	(0.103)
Observations	62,225	62,225	62,225	62,225	62,225	62,225
R-squared	0.616	0.616	0.616	0.616	0.616	0.616

Note: The table reports estimates of equation (32). All specifications include the full set of controls, fixed effects, and sample corrections as in column (7) of Table 1. Standard errors are clustered at the country-industry level and presented in parentheses. **, *** indicate significance at 5, 10%-level, respectively.

Results proposition 2

Table 3: U.S. offshoring intensity, labor market rigidity, and industry volatility (baseline).

	Dependent variable: ln(U.S. offshoring intensity)$_{lit}$					
	(1)	(2)	(3)	(4)	(5)	(6)
$rigidity_{lt} \times volatility_i$	-9.032***	-5.415***	-5.443***	-2.034***	-2.153***	-1.965***
	(1.519)	(1.642)	(1.632)	(0.360)	(0.453)	(0.456)
$rule_{lt} \times specificity_i$		0.577***	0.647***	0.190***	0.101	0.090
		(0.052)	(0.087)	(0.064)	(0.082)	(0.083)
$\ln(credit/GDP)_{lt} \times dependence_i$		0.451***	0.170***	-0.118*	-0.181**	-0.181**
		(0.038)	(0.051)	(0.065)	(0.079)	(0.081)
$\ln(K/L)_{lt} \times Kintensity_i$		0.077***	-0.210***	0.017	0.018	0.012
		(0.021)	(0.067)	(0.015)	(0.020)	(0.020)
$H_{lt} \times Sintensity_i$		0.930***	0.110	-0.163	0.088	-0.010
		(0.088)	(0.126)	(0.211)	(0.280)	(0.285)
Country-year FE	yes	yes	yes	no	no	no
Industry FE	yes	yes	yes	no	no	no
Industry dummies×$\ln(GDPpc)_{lt}$	no	no	yes	yes	yes	yes
Country-industry FE	no	no	no	yes	yes	yes
Year FE	no	no	no	yes	yes	yes
Sample restriction (Wright)	no	no	no	no	yes	yes
Sample restriction (NT)	no	no	no	no	yes	yes
Sample selection correction	no	no	no	no	no	yes
Observations	105,933	92,696	92,696	89,839	60,086	59,063
R-squared	0.607	0.604	0.628	0.940	0.932	0.929

Note: The table reports estimates of equation (33) with ln(U.S. offshoring intensity)$_{lit}$ as a dependent variable. Standard errors are clustered at the country-industry level and presented in parentheses. *, **, *** indicate significance at 1, 5, 10%-level, respectively.

Results proposition 2

Table 4: U.S. offshoring intensity, labor market rigidity, and industry volatility (robustness).

	Dependent variable: ln(U.S. offshoring intensity)$_{lit}$					
	(1)	(2)	(3)	(4)	(5)	(6)
$rigidity_{lt} \times volatility_i$	-1.990***	-2.003***	-1.975***	-1.984***	-1.966***	-1.999***
	(0.456)	(0.455)	(0.456)	(0.455)	(0.455)	(0.455)
$rule_{lt} \times contractibility_i$(Nunn)	-0.526**					0.412
	(0.215)					(0.412)
$rule_{lt} \times contractibility_i$(Levchenko)		-2.450***				-3.053***
		(0.599)				(0.961)
$rule_{lt} \times contractibility_i$(Costinot)			0.391			0.088
			(0.265)			(0.302)
$rule_{lt} \times contractibility_i$(Bernard)				-1.051**		-0.193
				(0.451)		(0.717)
$\ln(credit/GDP)_{lt} \times tangibility_i$					-0.538***	-0.518***
					(0.184)	(0.184)
Observations	59,063	59,063	59,063	59,063	59,063	59,063
R-squared	0.929	0.929	0.929	0.929	0.929	0.929

Note: The table reports estimates of equation (33). All specifications include the full set of controls, fixed effects, and sample corrections as in column (6) of Table 3. Standard errors are clustered at the country-industry level and presented in parentheses. **, *** indicate significance at 5, 10%-level, respectively.

What have we learned?

- Demand **U** $\Rightarrow$ advantage of flexibility
- With cost of flexibility $\Rightarrow$ endogenous contracts
- Formal similarity between demand and cost **U**
- **O**: trade off b'w flexibility cost and factor cost
- Interaction b'w volatility of industry and flex.-cost of countries
- Intuitive predictions for offshoring supported by data