Appropriability of Intellectual Assets and the Organization of Global Supply Chains

Stefano Bolatto
University of Bologna

Alireza Naghavi
University of Bologna

Gianmarco Ottaviano
Bocconi University & LSE

Katja Zajc Kejžar
University of Ljubljana

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Background

Modern supply chains are becoming more and more "global" in nature (suppliers located across different countries).

- **Integration** vs. **outsourcing** decision ('make or buy')

Central issue: **incomplete contracts** and **contract enforcement** (Antràs 2003, 2005; Antràs & Helpman 2004, 2008; Grossman & Helpman 2002, 2003, 2005) → Mostly 'upstream sourcing' (Del Prete & Rungi 2017)

Transaction cost theory stresses trade-off between gains from specialized outsourced supply and associated losses from hold-up problems → ***better contracting institutions*** *increase incidences of* ***outsourcing***

- Williamson (1971, 1975, 1985): better institutions **reduce hold-up problems** associated with outsourcing

Property right theory stresses trade-off between gains from stronger outsourced supplier's incentives and associated losses from weaker rent extraction → ***better contracting institutions*** *increase incidences of* ***integration***

- Grossman & Hart (1986); Hart & Moore (1990): better institutions **reduce the need to create investment incentives** through outsourcing

Evidence? Most find support for **property right theory** (from Corcos et al. , 2013, to Eppinger & Kukharskyy, 2017)

Few (e.g. Defever & Toubal, 2013) find support for **transaction cost theory**.

Our contribution

The focus of all existing works is on the contractual enforcement of input specifications.

Our aim is to highlight the parallel importance of the appropriability of intellectual property.

- *Incomplete protection of **Intellectual Property Rights (IPR)** entails additional **imitation risk** from outside competitors **on top of hold-up problem** between firm and supplier.*

In particular, we study how **IPR protection** in the country of input production **may affect the optimal allocation of ownership rights** along the value chain.

Two building blocks:

- ✓ A simple theory of knowledge dissipation in sequential production
- ✓ Property rights model of sequential production à la Antràs & Chor (2013), Alfaro et al. (2017)

Our contribution

Model the **risk of imitation** in sequential global supply chains based on input IPR intensity and strength of IPR in production location.

- Bring this concept into the Antràs & Chor (2013) **property rights model** of the sequential supply chain.

The firm's decision to integrate or to outsource a given stage in production depends on:

- ✓ **Relative position of stage** within the production line
- ✓ **Sequential substitutability/complementarity** of supplier investments along the chain
- \+ **Possibility of imitation** by competitors distorting suppliers' investment incentive structure under both integration and outsourcing (same set of available contracts)

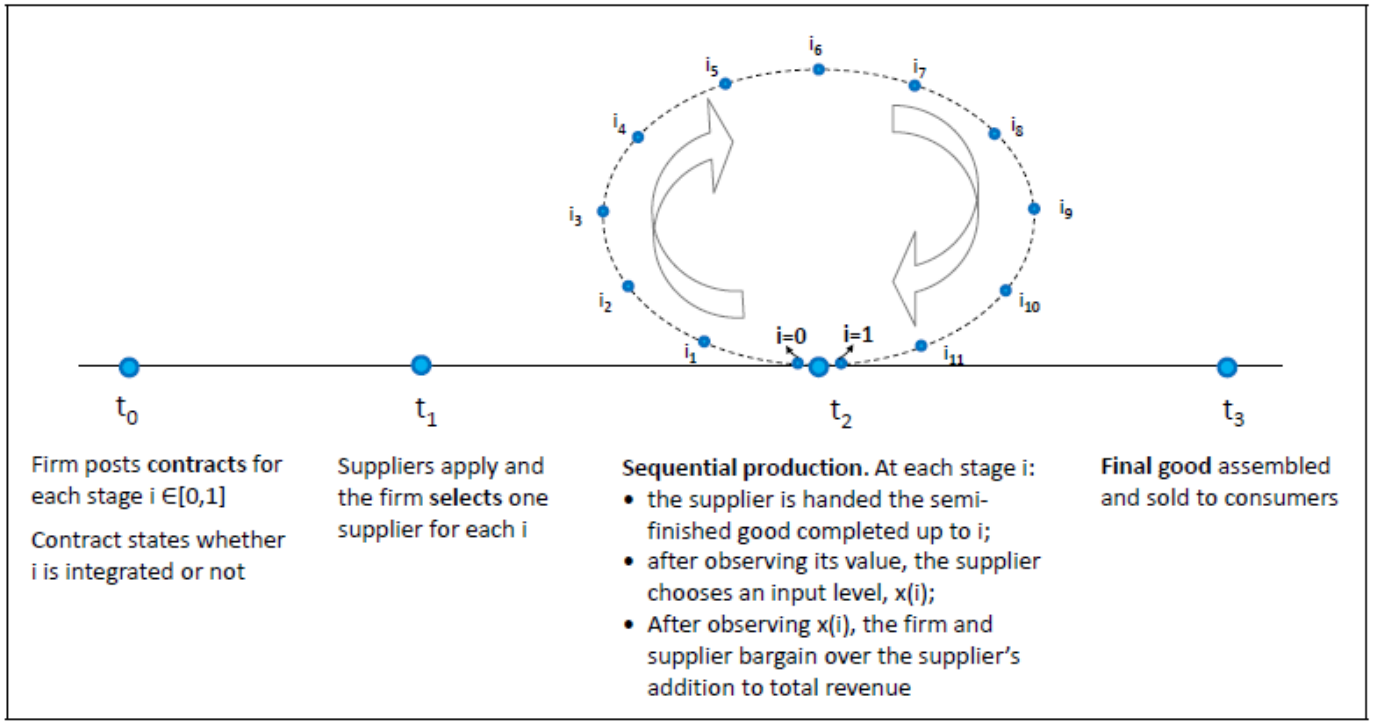
Theoretical predictions tested on firm-level data, using **trade, FDI and financial data on Slovenian firms and their subsidiaries** to measure propensity to integrate a given stage based on (i) upstreamness, (ii) complementarity of inputs, and (iii) IPR protection in the host country [→ (iv) IPR intensity of input].

Imitation and sequential production

- Firm:
  - Supplies a differentiated final product through sequential production stages ('value chain') → Is positioned 'downstream'.
  - Has exclusive knowledge of the production technology of the final product and all inputs at each stage of the value chain.
- At each stage **technology leaks** ('imitation') **unless the firm invests in IPR protection** → no investment at any stage allows competitors to steal the firm's knowledge, and thus copy its final product, destroying the surplus generated by the value chain.
- The **probability of imitation** and thus the firm's investment choice on IPR protection affects the incentives of suppliers to invest in the relationship with the firm.
- How this probability varies endogenously **across stages and countries** has crucial **implications for the firm's organization of the value chain**.

A model of sequential production

Antràs and Chor (2013), Alfaro at al. (2017) → property rights theory, sequential production, incomplete contracts.

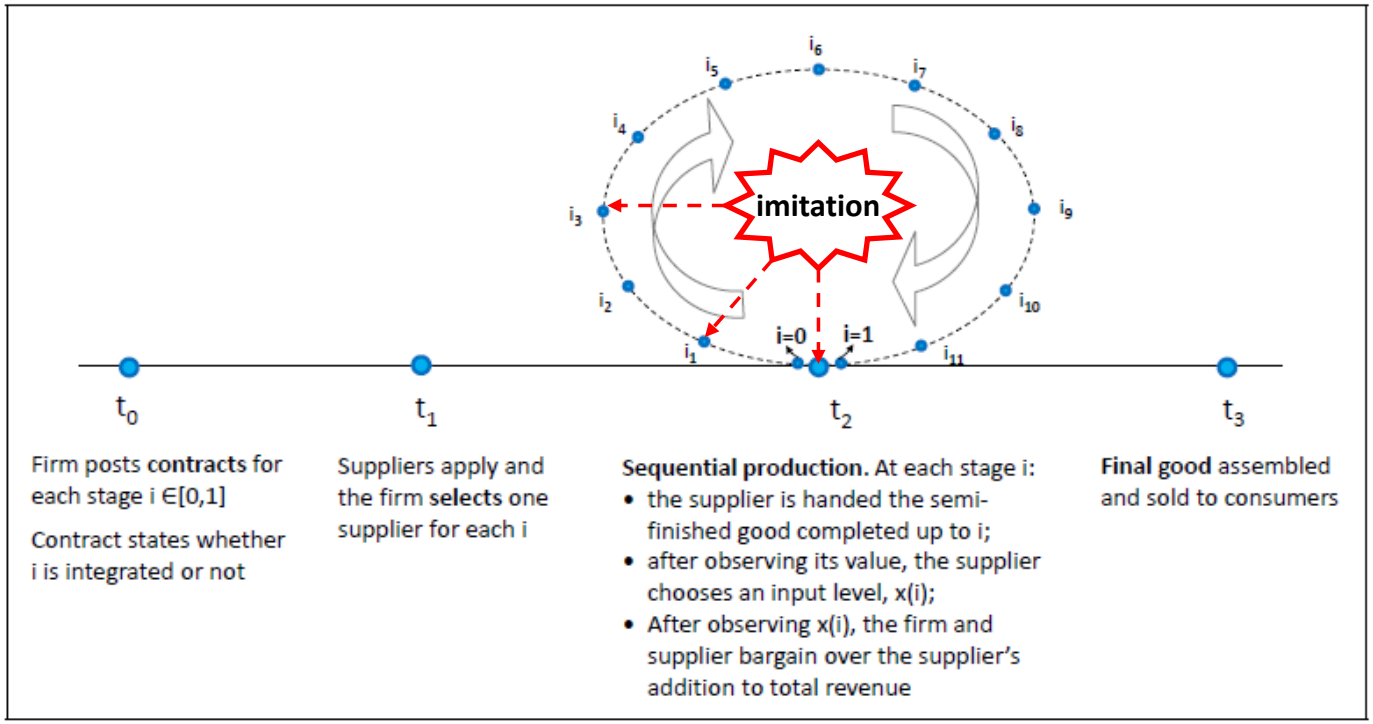


Note: i∈(**0**,**1**) indexes the sequence of inputs along the supply chain (i=0 most upstream)

Source: Alfaro et al (2017), Figure 2 Timing of Events

A model of sequential production with imitation

Antràs and Chor (2013), Alfaro at al. (2017) → Enter **imitation**.



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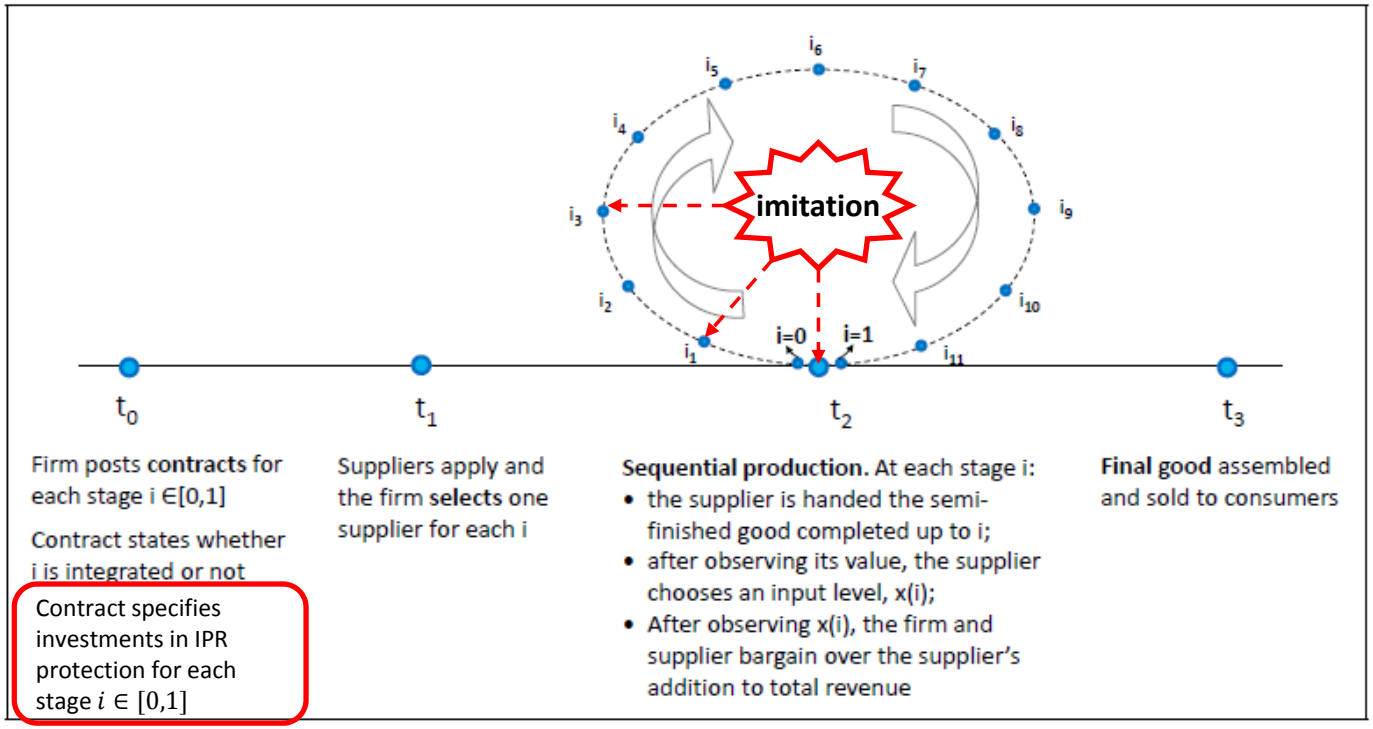

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Property rights and sequential production

At any given stage of production, **integration allows the firm to extract more surplus** from its supplier, but…

…**outsourcing leads supplier to invest relatively more** as it gets a larger share of surplus → this is the **positive direct differential effect** of outsourcing on supplier compared to integration.

Indirect differential effect ('spillover'): investment by an independent supplier affects the incentives to invest for all suppliers performing the subsequent stages in a way that depends on whether inputs are:

- **seq. complements** ($\rho > \alpha$) ⇒ indirect differential effect of outsourcing is **positive**.
- **seq. substitutes** ($\rho < \alpha$) ⇒ indirect differential effect of outsourcing is **negative**.

ρ = measure of output demand elasticity

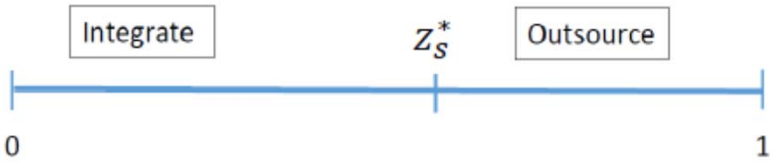
α = measure of inputs' substitutability in production ('technological substitutability')

Property rights and sequential production

Position of and **inter-relation** between **stages** affect firm organization via **supplier incentive structure** → Choice of where to place rent extraction vs. investment promotion.

Let $z \in (0, 1)$ index the sequence of inputs along the supply chain (z=0 most upstream)

- **Sequential Substitutes** → *upstream investment reduces marginal return of downstream investments.*



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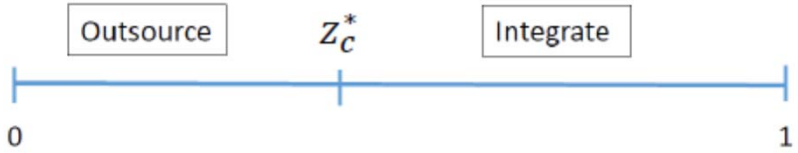

Input contractability and sequential production

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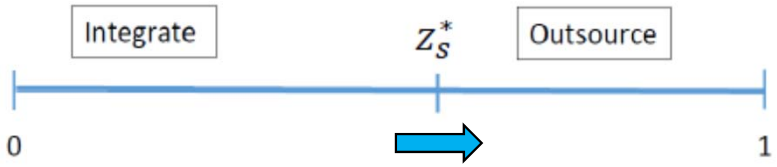

Alfaro et al. (2017): **improved contractibility reduces reliance on outsourcing** in the **downstream** part of the process to overcome distortions associated with inefficient investment → probability of integration increases but disproportionately downstream

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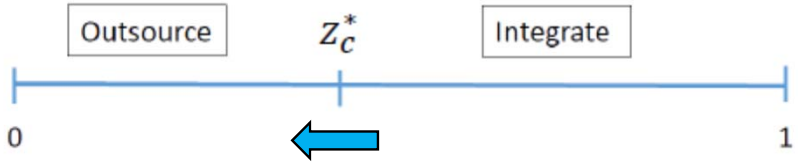

Alfaro et al. (2017): **improved contractibility reduces reliance on outsourcing** in the **upstream** part of the process to overcome distortions associated with inefficient investment → probability of integration increases but disproportionately upstream

Sequential production and imitation: Reprise

- Contract between firm and supplier is **incomplete in terms of input specifications, not in terms of intellectual property**:
  - No risk of dissipation of technological knowledge **within** the relationship (i.e. no value of knowledge for supplier outside its relation with the firm)
  - Firm's investment in intellectual property protection specified in the contract is **verifiable and enforceable**
- There is however **risk of imitation** from outsiders:

→ Let $\boldsymbol{z} \in (\mathbf{0}, \mathbf{1})$ index the sequence of inputs along the supply chain (z=0 most upstream) and $\boldsymbol{\varphi(z)} \in (\mathbf{0}, \mathbf{1})$ be the probability that input z is **not** imitated

- Firm decides (and writes in contract) organizational choice and IPR investment for every input before production starts → Considering **IPR intensity of input** (more IPR intensive inputs are more costly to protect) and quality of **IPR institutions in country**

Sequential production and imitation: Reprise

► Let $\omega(z)(\varphi(z))^{\lambda}$ be the **cost of IPR protection** for input z with IPR intensity $\omega(z)$ when the quality of IPR institutions is indexed by $\lambda > 1$ (recall $\varphi(z) \in (0,1)$)

→ For given IPR intensity ($\omega(z)$), the cost of IPR protection increases with the targeted probability of no imitation (larger $\varphi(z)$) and decreases with the quality of IPR institutions (smaller λ)

→ For given IPR institutions (λ), more IPR intensive inputs (larger $\omega(z)$) are more costly to protect

→ For given IPR intensity $\omega(z)$, it is increasingly difficult to protect additional aspects of intellectual property ($\lambda > 1$)

► $-\omega(z)(\varphi(z))^{\lambda}$ is super-modular in $\omega(z)$ and λ → a country with better IPR institutions has a **comparative advantage** in terms of protection of IPR intensive inputs

Sequential production and imitation: Reprise

- At time 0, when the firm decides organization and IP protection for $\forall z$, the expected value of the **final output** is

$$q = \theta \left(\int_0^1 (\varphi(z)x(z))^{\alpha} I(z)\, dz \right)^{1/\alpha}$$

- Optimal choice of IPR protection is such that the **probability of no imitation** satisfies FOC

$$\left(\frac{\varphi(z)}{\varphi(z')} \right)^{\lambda - \frac{\alpha}{1-\alpha}} = \frac{\omega(z')}{\omega(z)}$$

with $\boldsymbol{\lambda} - \frac{\alpha}{1-\alpha} > 0$ for SOC

- As more **IPR intensive inputs** are more costly to protect (larger ω), their optimally chosen **probability of no imitation is lower** (smaller φ)

→ The more so, the weaker the IPR institutions (smaller $\boldsymbol{\lambda}$)

Sequential production and imitation: Reprise

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- As more **IPR intensive inputs** are more costly to protect (larger ω), their optimally chosen probability of no imitation is **lower** (smaller φ)

→ The more so, **the weaker the IPR institutions** (smaller $\boldsymbol{\lambda}$)

- How $\omega(z)$ varies with z is an empirical issue → **For exposition assume $\boldsymbol{\omega'(z) > 0}$ → IPR intensity increases with downstreamness**

Sequential production and imitation: An example

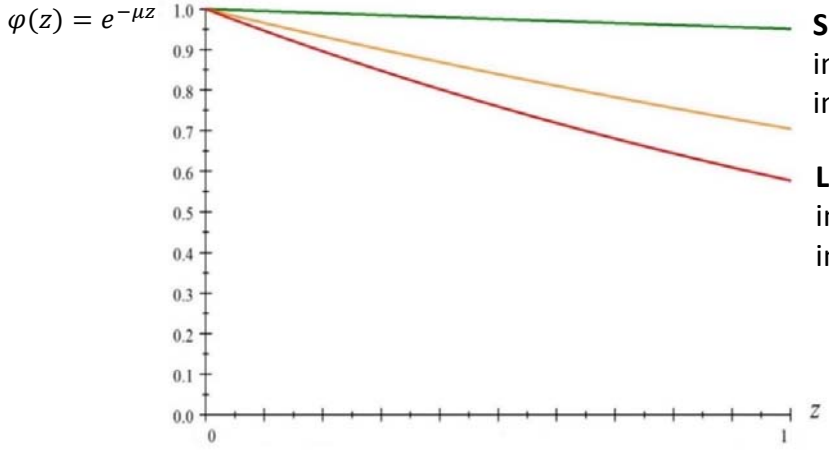
- Specifically, assume input IPR intensity $\boldsymbol{\omega(z) = e^{\omega z}}$ → IPR intensity increases **exponentially** with downstreamness

→ Cost of IPR protection $\boldsymbol{\omega(z)(\varphi(z))^{\lambda} = e^{\omega z}(\varphi(z))^{\lambda}}$ → **Optimally chosen IPR protection** decreases with downstreamness z as it satisfies

$$\frac{\varphi(z)}{\varphi(z')} = e^{-\mu\,(z-z')}, \qquad \mu \equiv \frac{\omega}{\lambda - \frac{\alpha}{1-\alpha}}$$

- Choose normalization of marginal cost of inputs such that the **probability of no imitation** is $\boldsymbol{\varphi(z) = e^{-\mu z}}$ → **decreases with downstreamness**

→ The more so, the larger the **relative IPR intensity** of downstream tasks (larger $\boldsymbol{\omega}$), the lower the **quality of IPR institutions** (smaller $\boldsymbol{\lambda}$) and the more technologically substitutable the inputs (larger $\boldsymbol{\alpha}$)

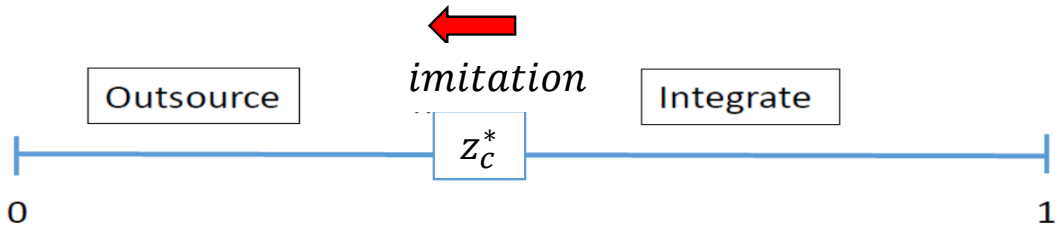


Small μ (low relative downstream IPR intensity/high quality of IPR institutions)/low inputs technological substitutability

Large μ (high relative downstream IPR intensity/low quality of IPR institutions/high inputs technological substitutability)

Predictions on the role of IPR (i)

Seq. complements case ($\rho > \alpha$):



Lack of IPR shifts the cut-off stage z_c^* towards left

- Trade-off between upstream incentives provision through outsourcing and downstream rent extraction through integration.
- **Direct effect (independent of sequentiality)**: imitation reduces the ability to use outsourcing to incentivize suppliers at all stages → **z_c^* falls (-)**
- **Indirect effect (due to sequentiality)**: as for given cut-off z_s^* imitation reduces the 'weight' of downstream rent extraction, the number of integrated stages increases to restore balance → **z_c^* falls (-)**

Predictions on the role of IPR (i)

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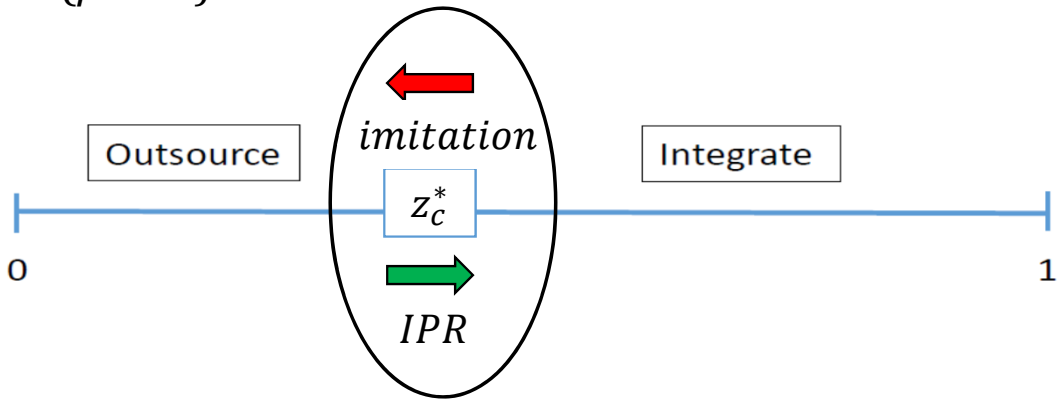


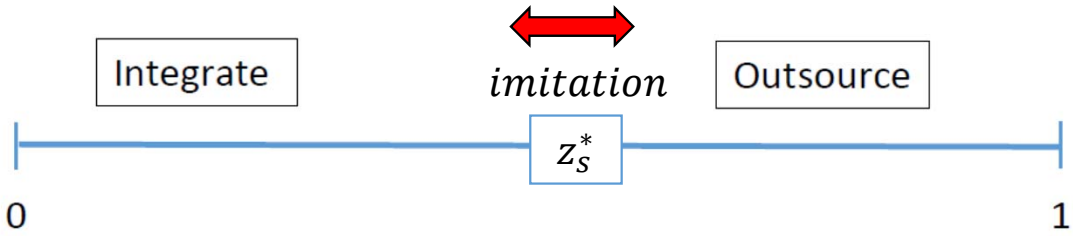
► When countries with stronger IPR institutions (larger λ) have a comparative advantage in IPR intensive inputs ($-d^2(e^{\omega z}\varphi(z)^{\lambda})/d\lambda d\omega>0$) and input IPR intensity is decreasing with upstreamness ($de^{\omega z}/dz>0$):

► With sequential complements, the probability of integration is **decreasing** in the strength of IPR institutions (**λ**) and **increasing** in the relative downstream IPR intensity of inputs (**ω**).

► The negative impact of IPR institutions (**λ**) on the probability of integration is **stronger** for higher relative downstream IPR intensity of inputs (**ω**).

Predictions on the role of IPR (ii)

Seq. substitutes case ($\rho < \alpha$):

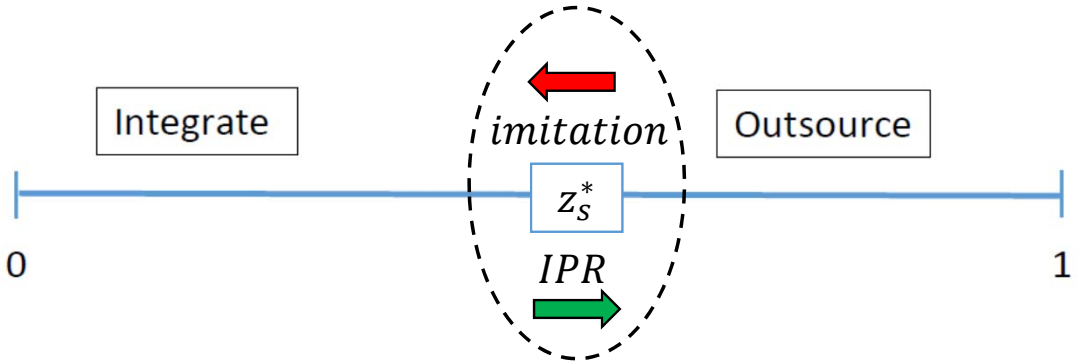


Lack of IPR shifts the cut-off stage z_S^* towards left:

- Trade-off between upstream rent extraction through integration and downstream incentives provision through outsourcing.
- **Direct effect (independent of sequentiality)**: imitation reduces the ability to use outsourcing to incentivize suppliers at all stages → **z_S^* rises (+)**
- **Indirect effect (due to sequentiality)**: as for given cut-off z_S^* imitation reduces the 'weight' of downstream incentive provision, the number of outsourced stages increases to restore balance → **z_S^* falls (-)**

Predictions on the role of IPR (ii)

Seq. substitutes case ($\rho > \alpha$):



► With sequential substitutes, the probability of integration is **increasing** in the strength of IPR institutions (**λ**) and **decreasing** in the relative downstream IPR intensity of inputs (**ω**).

► With sequential substitutes, for each input (**z**) the response of the optimal organizational choice to differences in the strength of IPR institutions is **less pronounced** than with sequential complements.

Data and outcome variable

We test our results using **transaction-level trade data on Slovenian manufacturing firms** (2007-2010), matched with:

(i) detailed information of origin/destination of inward/outward **FDI**

(ii) firm balance sheets

- 5,766 firms, imports from 87 countries, outward FDI with 37 partner countries

Slovenia → 2004 EU member, 2007 adopted the euro; **increasing involvement in GVC** (WTO index: 58.7 in 2011 – top OECD quartile), mostly strong **backward** participation (WTO, 2016)

Integration → Alfaro et al (2017)

- ✓ Use **I-O tables** to identify firm's inputs
- ✓ Exploit info on **core activity** of firm's affiliate
- ✓ Inputs that are imported from country where firm has **FDI** and are classified under **core activity of affiliate** (at 4-digit industry level) regarded as integrated → **dependent variable**: probability a firm *i* integrates input *h* for product *k* when sourcing from country *j* at time *t* ('probability of integration') → **1-** z_c^* for complements and z_s^* for substitutes
- ✓ For robustness: additional constraint that affiliates reports involvement in **intra-firm trade**

Explanatory variables

Upstreamness. We identify position of imported input in GVC with respect to firm's output (core export product at 6-digit HS) from **Alfaro et al. (2017)** → input output tables

IPR Protection. Log of **Park (2008)** index of patent protection in each host country (coverage, membership in international treaties, duration of protection, enforcement mechanisms, restrictions of patents rights)

Complementarity. Baseline → $\boldsymbol{\rho}$ **measure** of Antràs & Chor (2013): **complements** ($d\_compl = 1$): above-median import demand elasticity for a firm's core export product; **substitutes** ($d\_compl = 0$) otherwise.

Robustness with

► **(industry-level) proxy for $\boldsymbol{\alpha}$** → inputs classified within same industry feature higher technological substitutability

-- *Herfindahl index, how (6-digit) inputs are spread across different (3-digit) industries, above/below median*

► $\boldsymbol{\rho}$ x $\boldsymbol{\alpha}$ (**ind.**) → product of the above two measures, still industry-level

► $\boldsymbol{\rho}$ - $\boldsymbol{\alpha}$ (**elast.**) → demand elasticity of the core products vs. weighted average demand elasticity of all intermediates for the firms, firm-level (variant of the proxy of Alfaro et al, 2017)

Controls

- ✓ **Firm-specific controls** → age, size, capital intensity of production, labor productivity, export orientation, financial leverage (debt-to-assets ratio).
- ✓ **Annual dummy variables** → control for macroeconomic shocks.
- ✓ **Partner-country dummies** → country-specific time-invariant effects.
- ✓ **Industry fixed effects** → industry: core export product at 1-digit HS level.
- ✓ **[Downstream IPR intensity** → industry: whether input R&D intensity increases downstream**]**
- ✓ **[Relative Downstream IPR intensity** → firm: rate at which input R&D intensity increases downstream**]**

Descriptive statistics

	Substitutes (d_compl =0)		Complements (d_compl =1)	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**
d_OutFDI	0.1856	0.389	0.1942	0.396
d_OutFDI_bilateral	0.0371	0.189	0.0431	0.203
d integr	0.0007	0.027	0.0009	0.029
d integr_vert	0.0006	0.025	0.0007	0.026
Upstreamness	2.527	1.076	2.513	1.075
Import demand elasticity	0.869	0.194	1.582	4.550
Inputs demand elasticity	1.128	1.946	1.220	1.107
Industry Herfindahl index	0.714	0.077	0.689	0.115
IPR index	4.410	0.357	4.413	0.354
Rule of law index	1.045	0.780	1.011	0.794
Age	14.350	7.385	14.194	7.463
Employment	61.857	369.294	49.708	171.058
Ex-Propensity	0.302	0.322	0.301	0.322
K-intensity	84,363	388882	80,424	280194
L-productivity	42,799	83407	41,026	60307
Debt assets ratio	0.645	0.836	0.650	0.368
No of observations	475,861		360,531	

Results - Full sample specification ('triple interaction')

- Disaggregated at firm-year-product-country level: integration of an input from a country in a given year by a firm

	(1) Probit, ρ	(2) Probit C-M, ρ	(3) RE probit, ρ	(4) RE probit, ρ	(5) RE probit, ρ
Comp	11.927**	12.244**	25.370***	39.761***	38.648***
	(5.479)	(5.526)	(8.399)	(12.300)	(12.917)
lnIPR	0.774	0.751	-1.864	-3.157	4.198
	(2.256)	(2.364)	(3.845)	(5.530)	(9.447)
Comp*lnIPR	**-7.793****	**-8.001****	**-16.553*****	**-26.118*****	**-25.323*****
	(3.737)	(3.764)	(5.626)	(8.177)	(8.688)
Upstr	0.634	0.669	0.099	-0.787	0.725
	(0.945)	(0.932)	(2.077)	(3.265)	(4.124)
Comp*Upstr	**-6.430***	**-6.619***	**-12.371****	**-17.426****	**-18.409*****
	(3.498)	(3.565)	(5.153)	(7.386)	(6.993)
lnIPR*Upstr	-0.579	-0.602	-0.401	0.152	-0.999
	(0.698)	(0.690)	(1.423)	(2.221)	(2.809)
Comp*lnIPR*Upstr	**4.186***	**4.308***	**8.078****	**11.505****	**12.180*****
	(2.318)	(2.360)	(3.426)	(4.882)	(4.673)
Country dummies	yes	yes	**no**	**no**	**yes**
time dummies	yes	yes	yes	yes	yes
Industry dummies	yes	yes	**no**	**yes**	**yes**
Observations	615,847	611,495	791,911	725,141	615,847

As in Antràs & Chor (2013): for **complements**, outsourcing → upstream integration → downstream

- Includes lagged firm characteristics (1-5), firm characteristics (2); gravity variables (3-4); constant term (1-5)

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Observations	615,847	611,495	791,911	725,141	615,847

The probability that any given task is integrated decreases, the more so the more upstream the task is

For **complements**, stronger protection of IPR decreases reliance on integration

This is the more so, the more downstream we go along the supply chain.

- Includes lagged firm characteristics (1-5), firm characteristics (2); gravity variables (3-4); constant term (1-5)

Results - Split sample specification

	(1) RE prob, ρ Comp	(2) RE prob, ρ Subst	(3) RE prob, ρ Comp	(4) RE prob, ρ Subst
lnIPR	**-26.81*** **	**-2.503**	**-22.36***	**-16.45**
	(5.498)	(5.975)	(12.489)	(17.889)
Upstr	-14.58***	-1.773	-20.91***	-2.092
	(5.169)	(3.870)	(6.347)	(5.672)
lnIPR*Upstr	**8.822** **	**0.730**	**13.050*** **	**0.786**
	(3.430)	(2.647)	(4.200)	(3.813)
Rule_of_law				
Rule_of_law *Upstr				
Country dummies	no	no	yes	yes
Time dummies	yes	yes	yes	yes
Industry dummies	yes	yes	yes	yes
Observations	308,518	390,751	246,902	312,789

For **complements**, IPR enforcement decreases integration, effect weaker upstream (**more outsourcing downstream**)

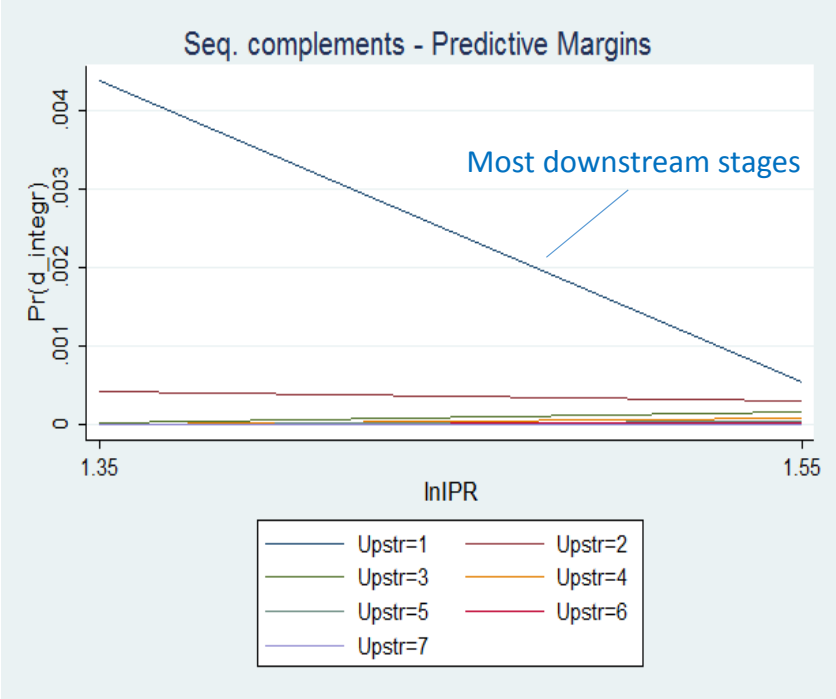
Effect is not statistically significant effect for **substitutes**!

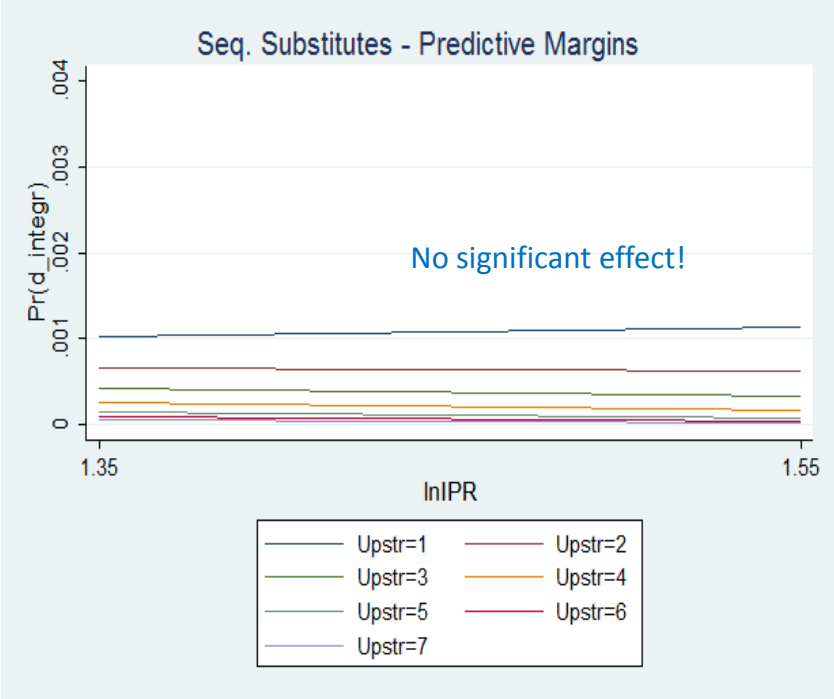
Results - Split sample specification

	(1) RE prob, ρ Comp	(2) RE prob, ρ Subst	(3) RE prob, ρ Comp	(4) RE prob, ρ Subst	(5) RE prob, ρ Comp	(6) RE prob, ρ Subst	(7) RE prob, ρ Comp	(8) RE prob, ρ Subst
lnIPR	**-26.81*** **	**-2.503**	**-22.36***	**-16.45**				
	(5.498)	(5.975)	(12.489)	(17.889)				
Upstr	-14.58***	-1.773	-20.91***	-2.092	-0.664***	-0.708***	-0.116	-0.774***
	(5.169)	(3.870)	(6.347)	(5.672)	(0.202)	(0.203)	(0.159)	(0.193)
lnIPR*Upstr	**8.822****	**0.730**	**13.050*****	**0.786**				
	(3.430)	(2.647)	(4.200)	(3.813)				
Rule_of_law					**-0.703**	**-1.246****	**5.316*****	**-5.076*****
					(0.573)	(0.603)	(1.894)	(1.807)
Rule_of_law *Upstr					**-0.248**	**0.016**	**-0.586*****	**0.039**
					(0.221)	(0.216)	(0.192)	(0.211)
Country dummies	no	no	yes	yes	no	no	yes	yes
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes
Industry dummies	yes	yes	yes	yes	yes	yes	yes	yes
Observations	308,518	390,751	246,902	312,789	340,984	444,657	277,561	362,193

When considering **rule of law** instead of IPR ... opposite results, in line with AC property rights story (compl.)

Predictive Margins





Alternative measures of complements/substitutes

	(1) RE Probit α (ind) Comp	(2) RE Probit α (ind) Subst	(3) RE Probit ρ x α (ind) Comp	(4) RE Probit ρ x α (ind) Subst	(5) RE Probit ρ-α (elast.) Comp	(6) RE Probit ρ-α (elast.) Subst
lnIPR	-16.559***	-2.614	-15.179***	-1.376	-15.179***	-0.382
	(2.961)	(5.760)	(2.952)	(4.903)	(2.784)	(6.632)
Upstr	-7.633***	0.560	-7.625***	0.096	-7.560***	-0.449
	(2.571)	(3.253)	(2.391)	(2.965)	(2.355)	(3.832)
lnIPR*Upstr	4.761***	-1.169	4.765***	-0.929	4.757***	-0.232
	(1.734)	(2.243)	(1.609)	(2.026)	(1.591)	(2.604)
Country dummies	no	no	no	no	no	no
Time dummies	yes	yes	yes	yes	yes	yes
Industry dummies	yes	yes	yes	yes	yes	yes
Observations	408,896	414,750	336,484	371,962	265,050	396,920

Further robustness checks

- Adding **country fixed effects** in the baseline model (split sample, RE probit) … lower significance of the direct effect of IPR as expected, but interaction persists

- **Adding** partner-countries' **institutional variables** (likely correlated with IPR) from Worldwide Governance Indicators (2015) and GDP pc. + their interactions with upstreamness

- One-country model, many-countries world: subsample of firms with **increasing concentration of sourcing from one country**, results hold coefficient increasing with thresholds at 10% -20% -30%

- Other checks:

  - additional constraint of **positive intra-firm trade** by subsidiary to define integration: assure **vertical FDI**

  - subsample of **intermediate** or capital good import transactions

  - restricting to firms involved in outward FDI (removing firms that **outsource all stages** performed abroad)

Concluding remarks

We provide novel insights on how IPRs shape the **organization of GVCs**:

- ✓ Better institutions in form of higher **IPR protection encourage outsourcing** in the case of investment complementarity along the GVC (opposite to contract enforcement)

  ⇒ can be explained by introducing **imitation** in the framework of **property rights theory**.

  - ▶ **Lack of IPR protection** induces firms to opt for **integration**.
  - ▶ **Sound IPR regime** allows firms to use **outsourcing** to create supplier incentives.

- ✓ IPRs relevant for **sequential complements** and relatively **downstream** stages but less so for sequential substitutes.

Caveats:

- ✓ Not a model of location choice: locations of production activities are given
- ✓ No ex-post adjustment in the organization of the GVC after imitation happens
- ✓ **Work in progress on predictions related to ω (relative downstream IPR intensity of inputs) and α (substitutability of inputs in production)**