R&D Matters for Service Exports as Much as for Manufacturing

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Global trade is fragmenting, but services keep growing.

- Geoeconomic fragmentation is reshaping cross-border flows.
  - tariffs, export controls, reshoring, ...
- Merchandise trade has stagnated since 2008.
- Services trade has kept growing: 6% of world GDP (1975) $\rightarrow$ 14% (2023).
  - ICT makes once non-tradable services (legal, finance, software) deliverable across borders.
- **The stakes for Korea** (and other export-oriented economies)
  - Services = 60% of GDP, but a small share of exports
  - Export mix concentrated in low-value categories (transport, travel, trade-related).
  - Knowledge-intensive segments lag behind global trends.

Research questions

- **Starting point**: How can the government promote service exports?
- **R&D support?** They were built for manufacturing. Do they work for services too?
- With this big question in mind, this paper asks the following:

1. Does R&D raise service firms' export *entry* (extensive) and export *value* (intensive)?
2. How does the R&D effect in services *compare* to manufacturing?
3. How does the R&D–export link vary *across service industries* and *firm characteristics*?

How does R&D help exports — and why services may differ?

- In **manufacturing**, R&D lifts exports through clear channels:
  - Better product quality, lower costs, differentiation.
  - (Bernard & Jensen 1999; Aw, Roberts & Xu 2011; Lileeva & Trefler 2010)
- In **services**, this link may weaken:
  - Intangible, simultaneous production & consumption — hard to standardize and ship.
  - Depend on tacit knowledge, relationships, human capital.
  - Innovation often process-based — poorly captured by R&D statistics.
  - Yet some services (e.g. software) scale globally at near-zero marginal cost.

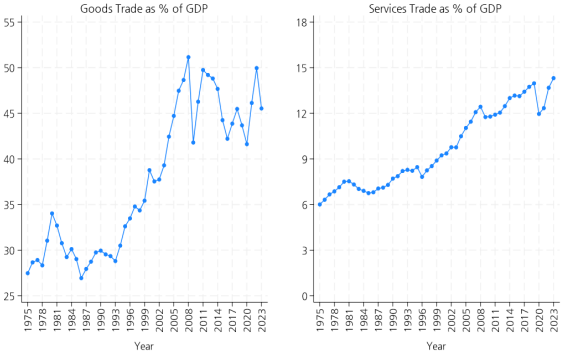
$\Rightarrow$ Whether R&D promotes service exports is an empirical question.

Method, Findings, and Contribution

- ML for causal inference in trade (still, *selection on observables*)
  - Causal Forest (Wager & Athey 2018) + DML (Chernozhukov et al. 2018)
  - Provides first systematic Conditional ATE comparison of services vs. manufacturing.
- Innovation & exports beyond manufacturing
  - R&D-investing service firms have a 9.5 %p higher export-entry probability.
    - ⋆ larger than manufacturing's 8.2 %p.
  - Extends Bernard & Jensen; Aw, Roberts & Xu (2011); Lileeva & Trefler (2010).
- Strong complementarity between R&D and intangible assets on exports
  - R&D support works best bundled with intangible-asset accumulation.

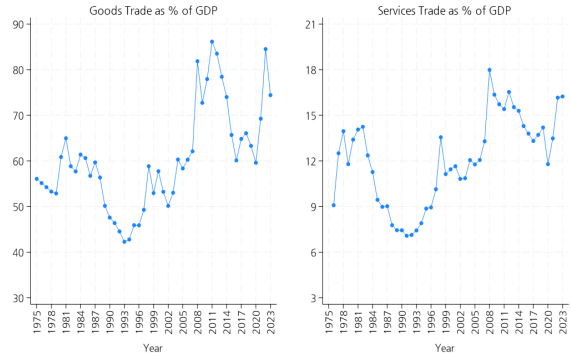
Fact 1: Services trade has kept growing — but not in Korea

(a) World



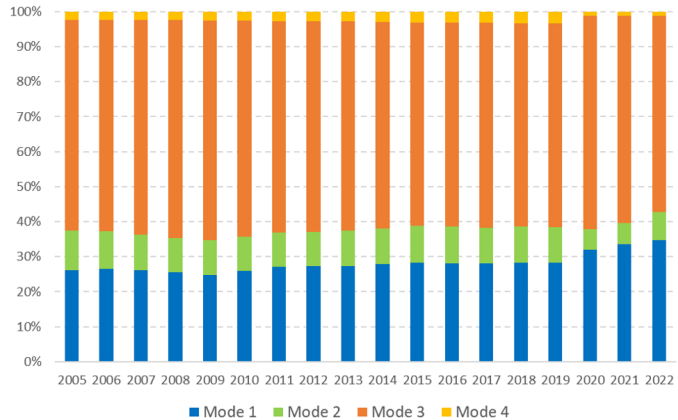
World services trade rise steadily to 14% of GDP.

(b) Korea



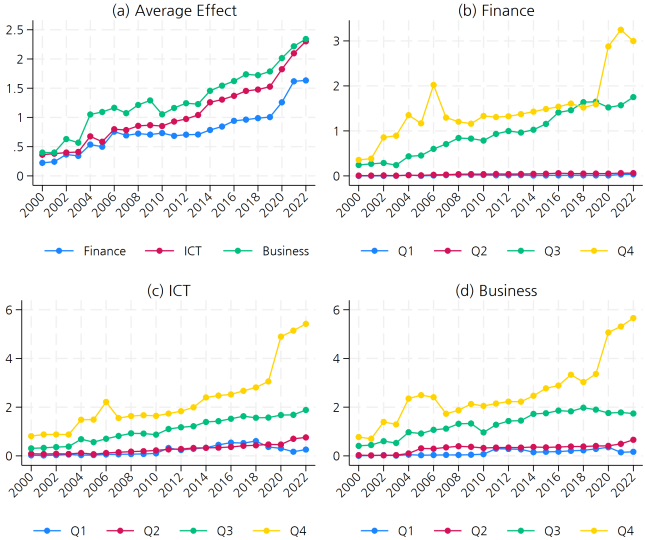
Korea's services trade flatten near 16% since 2008.

Fact 2: Digital delivery (Mode 1) drives growth



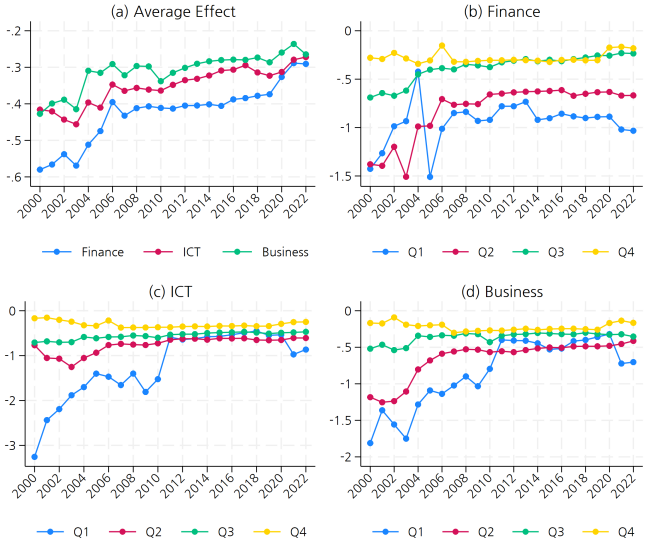
- Mode 1 (cross-border / digital)
  - 28% (2019) $\rightarrow$ 35% (2022)
- Computer services
  - \$365bn (2005) $\rightarrow$ \$826bn (2022)
- Mode 2 (travel) falls 26% $\rightarrow$ 20%.
- Korea still tilted toward freight & travel.
  - 15% of service exports (world 8.5%)

Fact 3: Border effects decline — gains concentrate at the top



- **Border effect** = Ratio of international to domestic service trade (%)
  - higher ratio → lower border friction
- ICT & business services exceed 2% by 2022.
- High-income (Q4) firms reach ∼5.7%.
- Low-income (Q1) stagnate near 0.3%.

Fact 4: Distance penalty weakens — with diminishing returns



- **Distance effect** = Gap in distance elasticity between international & domestic trade (%p)
  - closer to 0 $\rightarrow$ weaker distance penalty.
- Distance effects shrink.
  - $-0.58 \rightarrow -0.29$ for finance
- But the pace has slowed since the late 2010s.

Takeaway from the stylized facts

- Digital transformation *created* export opportunities.
  - Shrinking border frictions, expanding Mode 1 $\rightarrow$ **More services are becoming tradable**.
- But gains concentrate in high-income countries.
  - Korea lags in high-value segments, despite well-developed digital infrastructure.
- Digital infrastructure is necessary but not sufficient.
  - Firm-level capability is what turns opportunity into exports.
- Can service R&D play a role?

Empirical Strategy

- R&D investment is endogenous.
  - Reverse causality: firms expecting export success invest more in R&D.
  - Omitted variables: managerial quality, innovation culture, networks drive both.
- Treatment effects are heterogeneous.
  - A single average coefficient hides who benefits.
- Our approach: **Causal Forest + Double Machine Learning** with cross-fitting.
  - Estimates firm-level CATEs while flexibly controlling for confounders.
- **Caveat:** Identification still rests on selection-on-observables.

Causal Forest: heterogeneous treatment effects

- Conditional Average Treatment Effect for firm i:

$$\tau(X_i) = E[\, Y_i(1) - Y_i(0) \mid X_i]$$

- Trees split to maximize treatment-effect heterogeneity, not outcome variance:

$$\Delta(S_L, S_R) = \frac{|S_L|\,|S_R|}{|S_L| + |S_R|} \left(\hat{\tau}_{S_L} - \hat{\tau}_{S_R}\right)^2$$

- Honest splitting (Athey & Imbens 2016): separate samples to choose splits vs. estimate effects $\Rightarrow$ valid confidence intervals.
- CATE = average over B trees; asymptotically normal.

Double Machine Learning with cross-fitting

- Partially linear model:

$$Y_i = \tau(X_i)\, W_i + g(X_i) + \epsilon_i, \qquad W_i = m(X_i) + \eta_i$$

- **Stage 1 — orthogonalize** (Regression Forests, $K = 5$ folds):

$$\tilde{Y}_i = Y_i - \hat{Y}(X_i), \qquad \tilde{W}_i = W_i - \hat{W}(X_i)$$

- **Stage 2 — Causal Forest on residuals:**

$$\hat{\tau}_L = \frac{\sum_{i \in L} \tilde{W}_i\, \tilde{Y}_i}{\sum_{i \in L} \tilde{W}_i^2}$$

- Cross-fitting $\Rightarrow$ flexibly removes confounding while keeping inference valid.

Four estimation models

- Two export margins $\times$ two treatment forms:

	Binary (R&D dummy)	**Continuous** (log R&D)
Extensive	Model 1	Model 2
(entry prob.)	ΔP(export)	semi-elasticity
Intensive	Model 3	Model 4
(log export value)	% effect on value	R&D elasticity

- Main interest: Models 1 and 2 (entry is the key barrier for services).
  - Models 3 and 4 illuminate expansion among existing exporters.

Data

- Survey of Business Activities (Statistics Korea), 2006–2022.
  - Extensive-margin sample: 188,257 firm-years, 22,113 firms.
  - Manufacturing 99,742 (53%); Services 88,515 (47%).
  - Intensive-margin sample: 101,467 exporters (services only 22.4%).
- **Treatment:** R&D expenditure / status (47.3% invest).
- **Outcome:** export status & value (53.9% export).
- **11 controls:**
  - size, assets, IP rights, value added, group & subsidiary structure
  - year and 2-digit industry fixed effects
- `grf` package in R; seed = 42.

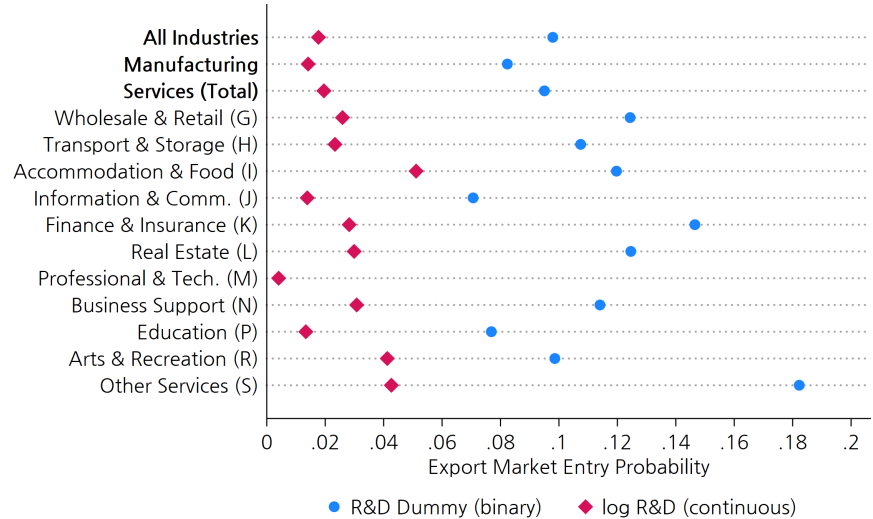
Result 1: R&D–entry link similar; intensity gap is large

R&D and export performance: services vs. manufacturing

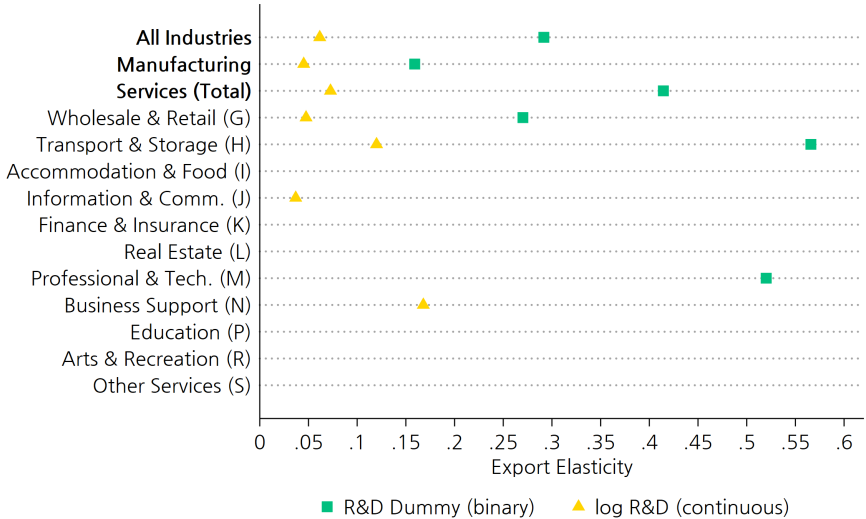
Model	Services	Manufacturing	Diff.
1: Extensive × Binary	0.095*** (0.004)	0.082*** (0.003)	0.013
2: Extensive × Continuous	0.020*** (0.001)	0.014*** (0.000)	0.005
3: Intensive × Binary	0.414*** (0.045)	0.159*** (0.021)	0.255
4: Intensive × Continuous	0.073*** (0.007)	0.045*** (0.003)	0.028

Note: Overlap-weighted AIPW sub-population ATE; SE in parentheses; *** $p < 0.01$.

Result 2: Industry heterogeneity: extensive margin



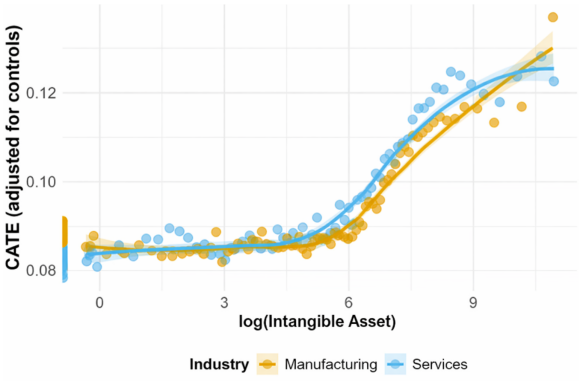
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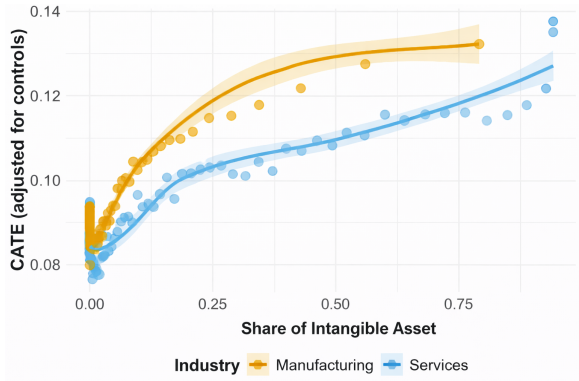
Result 3: Complementarity with intangible assets

- CATE rises nonlinearly: threshold at log 6–7 ($\approx$ 0.5–1bn won) and ratio 25–50%.

(a) Intangible asset scale (log)



(b) Intangible asset ratio



Robustness: Causal Forest vs. regression

- Same qualitative conclusions under traditional regression:

Model	Sector	Causal Forest	Regression	Diff.
1: Ext. × Bin.	Services	0.095***	0.074***	+0.021
	Manufacturing	0.082***	0.123***	−0.041
2: Ext. × Cont.	Services	0.020***	0.013***	+0.007
	Manufacturing	0.014***	0.024***	−0.010
3: Int. × Bin.	Services	0.414***	0.148***	+0.266
	Manufacturing	0.159***	0.235***	−0.076
4: Int. × Cont.	Services	0.073***	0.029***	+0.044
	Manufacturing	0.045***	0.057***	−0.012

- Regression imposes a single linear effect; with heterogeneous, nonlinear service effects, this understates the intensive margin (0.41 vs 0.15).

Conclusion and policy implications

What we find

1. R&D–export entry link similar across sectors, modestly larger in services.
2. R&D–export intensity link much larger in services, with wide industry variation.
3. Strong complementarity between R&D and intangible assets, with clear threshold effects.

Policy implications

- The R&D–export link in services is at least as strong as in manufacturing, a case for not excluding services from R&D support.
- Begin where R&D and exports are rising in services (e.g., business services) and ask *how* government can best support it.

Appendix: Estimation procedure

- **Stage 1.** $K = 5$ folds stratified by 1-digit industry; Regression Forests (1,000 trees, min node 5, honest, subsample 0.5) predict $\hat{Y}, \hat{W}$ out-of-fold.
- **Stage 2.** Single Causal Forest on full sample (4,000 trees, min node 10, honest, `honesty.fraction`=0.5), cross-fitted nuisances via `Y.hat`/`W.hat`.
- **ATE.** `average_treatment_effect(target.sample="overlap")` — doubly-robust AIPW, overlap weights $\hat{e}(1 - \hat{e})$.
- **Robustness.** 80/20 split, Full+OOB, logit/linear FE — qualitatively similar.

Appendix: Gravity model (stylized facts)

- PPML structural gravity with domestic flows (Benz et al. 2022)
- **Border effect**: interact border dummy with year:

$$X_{ijt,k} = \exp\Big(\textstyle\sum_t \beta_1^t \, IB_{ij} \cdot YR_t + \beta_4 G_{ij} \cdot IB_{ij} + \eta_{itk} + \mu_{jtk} + \varepsilon_{ijtk}\Big)$$

- **Distance effect**: interact int'l/domestic distance with year:

$$X_{ijt,k} = \exp\Big(\beta_1 IB_{ij} + \textstyle\sum_t \beta_2^t \, ID_{ij} \cdot YR_t + \sum_t \beta_3^t \, DD_{ij} \cdot YR_t + \beta_4 G_{ij} \cdot IB_{ij} + \eta_{itk} + \mu_{jtk} + \varepsilon_{ijtk}\Big)$$

  - $\exp(\beta_1^t)$ = international/domestic trade ratio (border effect).
  - $\beta_2^t - \beta_3^t$ = distance effect (int'l vs. domestic distance elasticity).
  - ID, DD = log distance for international ($i \neq j$) vs. domestic ($i = j$) trade.

- Data: OECD BaTIS, ITPD-E, CEPII; 47 countries, 2000–2022.