Technology adoption and production organisation: Firm level evidence from India

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Introduction

- In New Trade Theory, firm heterogeneity influences the choice of production organization (Melitz, 2003;Helpman, 2006).
- However, the fundamental assumption that firm heterogeneity is captured through exogenously determined productivity differentials remains unsatisfactory.
- A new body of theoretical work that seeks to understand the sources of firm heterogeneity has emerged in recent years:
  - Technology investment, heterogeneous productivity and exporting (Yeaple, 2005; Bustos, 2007; Lileeva and Trefler, 2007).
  - Heterogeneity in imported inputs (Kugler and Verhoogen, 2008)
  - Knowledge capital as a source of FDI and outsourcing (Chen et al., 2008).

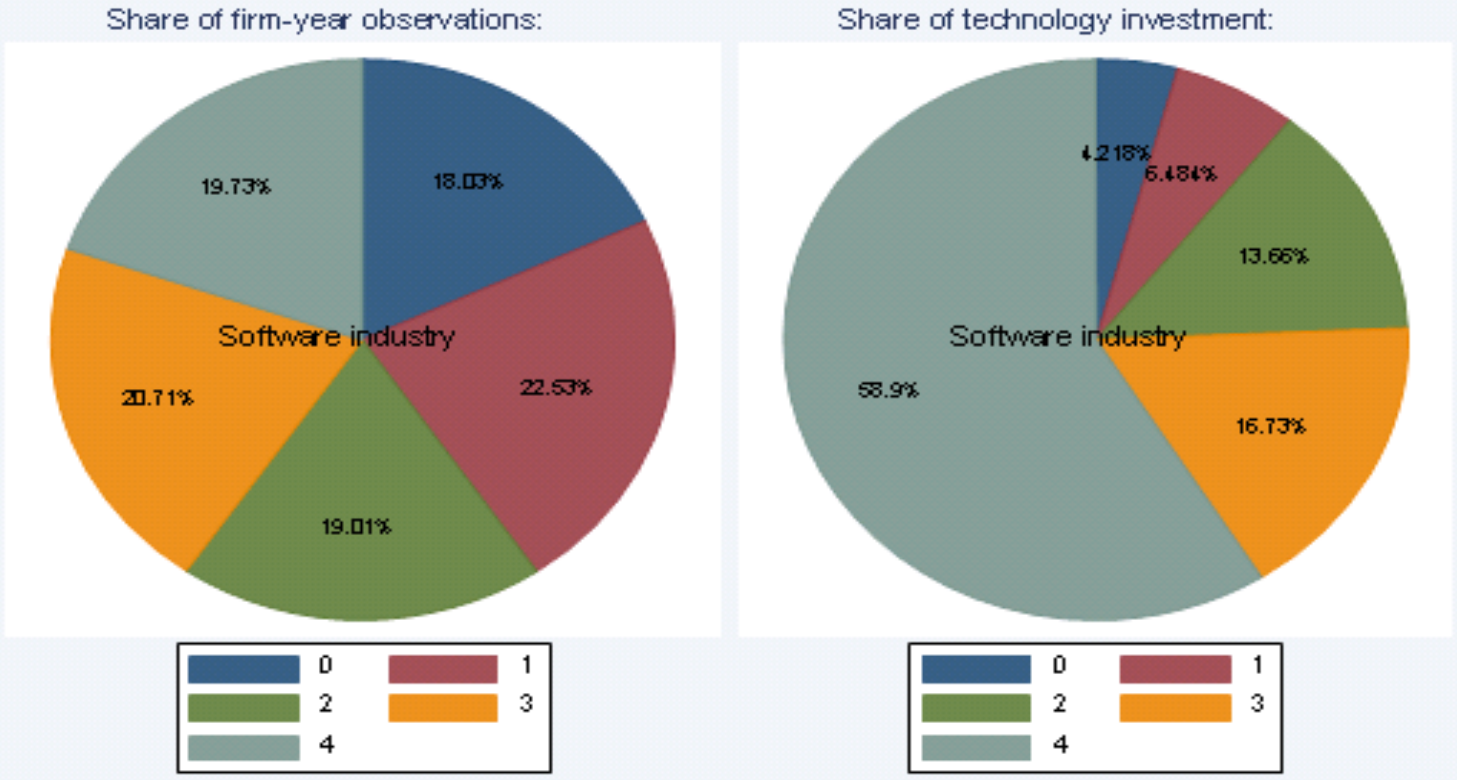
Introduction

The objectives of this paper:

1. To confront some of the predictions from the theoretical literature of technology investment and production organization using firm level data from two highly globalised sectors in India (software and pharmaceutical).
2. To inform future theoretical work towards the better understanding of the relationship between technology adoption and complex patterns of production organisation
   - ❑ Need to distinguish between trade in goods in services; inward and outward FDI; outsourcing of professional and manual jobs.
   - ❑ Especially need to account for the fact a firm can engage in many forms of production organisation!

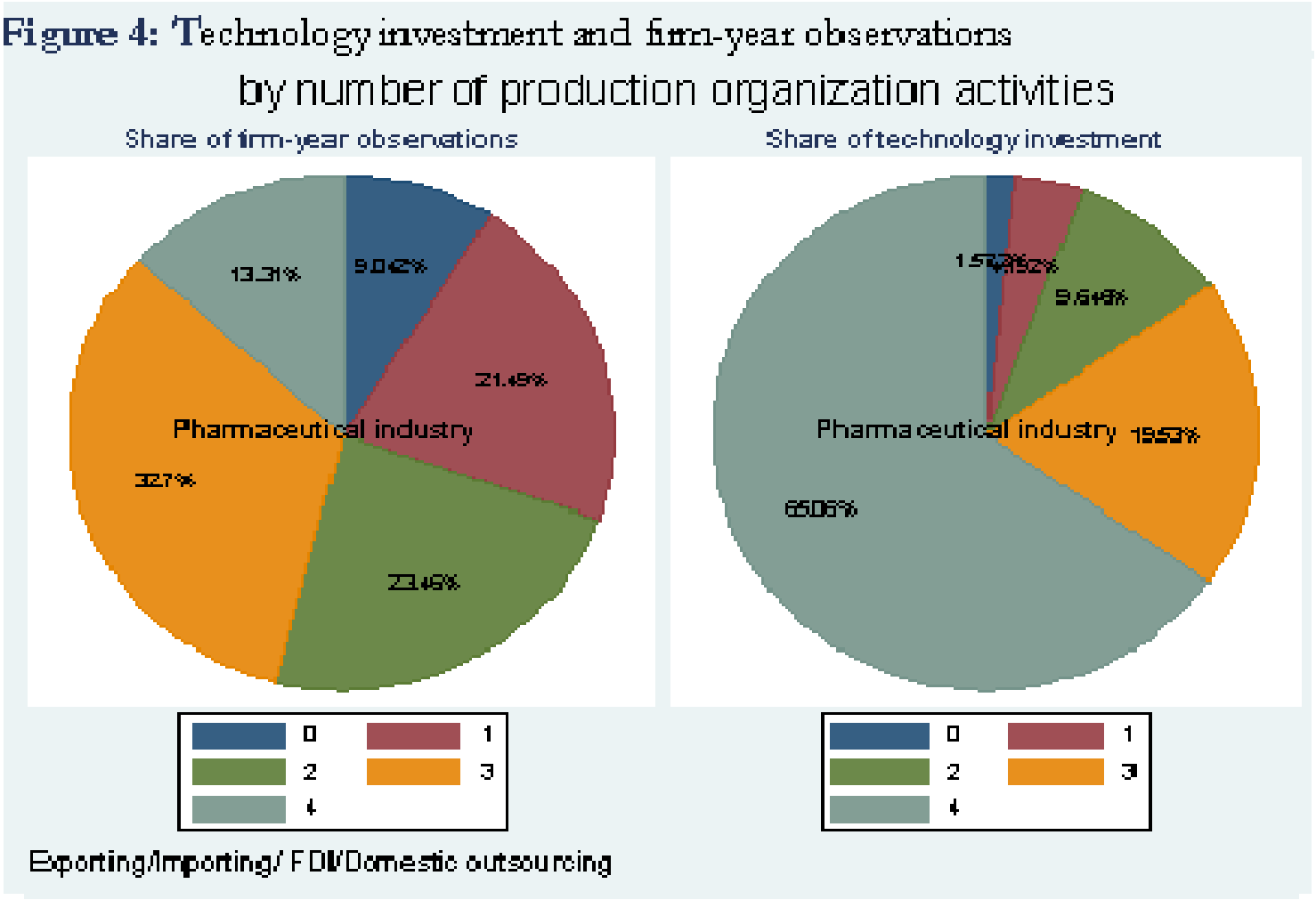
Introduction

Figure 3: Technology investment and firm-year observations
by number of production organization activities



Exporting/Importing/ FDI/Domestic outsourcing

Introduction



Introduction

Related empirical works:

- Joint decision of exporting and innovation
  - Baldwin and Gu (2004) for Canada
  - Bustos (2007) for Argentina
  - Aw et al. (2008, 2009) for Taiwan
  - Girma et al. (2008) for British and Irish firms.

Introduction

The upshot of this paper:

- There exists heterogeneous effects resulting from the choice of production organisation on the dynamics of technology investment, depending on industry characteristics, the interaction between the various forms of production organisation and the type of technology investment into account.

Outline of the rest of presentation

- Theoretical underpinnings
- Empirical approach
- Database description and sample characteristics
- Empirical findings
- Conclusions

Simple model

- Demand: $x = Ap^{-\varepsilon}$ and $x^* = A^* p^{-\varepsilon}$, $\varepsilon = \frac{1}{1-\alpha} > 1$
- Production: inputs costing c =1 can produce φ units of product
- With $\varphi = (\varepsilon - 1)^{\varepsilon - 1} \varepsilon^{-\varepsilon} \theta^{\varepsilon - 1}$ (measure of productivity)
- Fixed cost of exporting: f_E
- Per-unit (melting iceberg) trading cost: $\tau > 1$,

Theoretical Underpinnings
Models of exporting and technology investments

Simple model

- Maximum profits as a function of exporting decision (e)

$$\pi(e) = \varphi\left[A + e\tau^{-\varepsilon}A^*\right] - ef_X$$

- Export cut-off: $\varphi_X > \dfrac{f_X}{\tau^{-\varepsilon}A^*}$

- By paying a fixed cost, f_I, productivity increases to $\lambda\varphi$ $(\lambda > 1)$, (Technology investment)

$(r = 1)$

- Maximum profits by investing in technology

$$\pi_r(e) = \lambda\varphi\left[A + e\tau^{-\varepsilon}A^*\right] - ef_X - f_I$$

- Investment cut-off:

$$\varphi_T = \frac{f_I}{(\lambda - 1)\left[A + e\tau^{-\varepsilon}A^*\right]}$$

Theoretical Underpinnings
Models of exporting and technology investments

Simple model

- Profits when a firm does not invest and does not export

$$\pi_0 = \varphi A$$

- Profits when a firm invest and export

$$\pi_1 = \lambda \varphi \left[A + \tau^{-\varepsilon} A^*\right] - f_X - f_I$$

- Difference $\pi_1 - \pi_0$

$$\Delta \pi = \left[\varphi \tau^{-\varepsilon} A^* - f_X\right] + \left[(\lambda - 1)\varphi A - f_I\right] + \left[(\lambda - 1)\varphi \tau^{-\varepsilon} A^*\right]$$

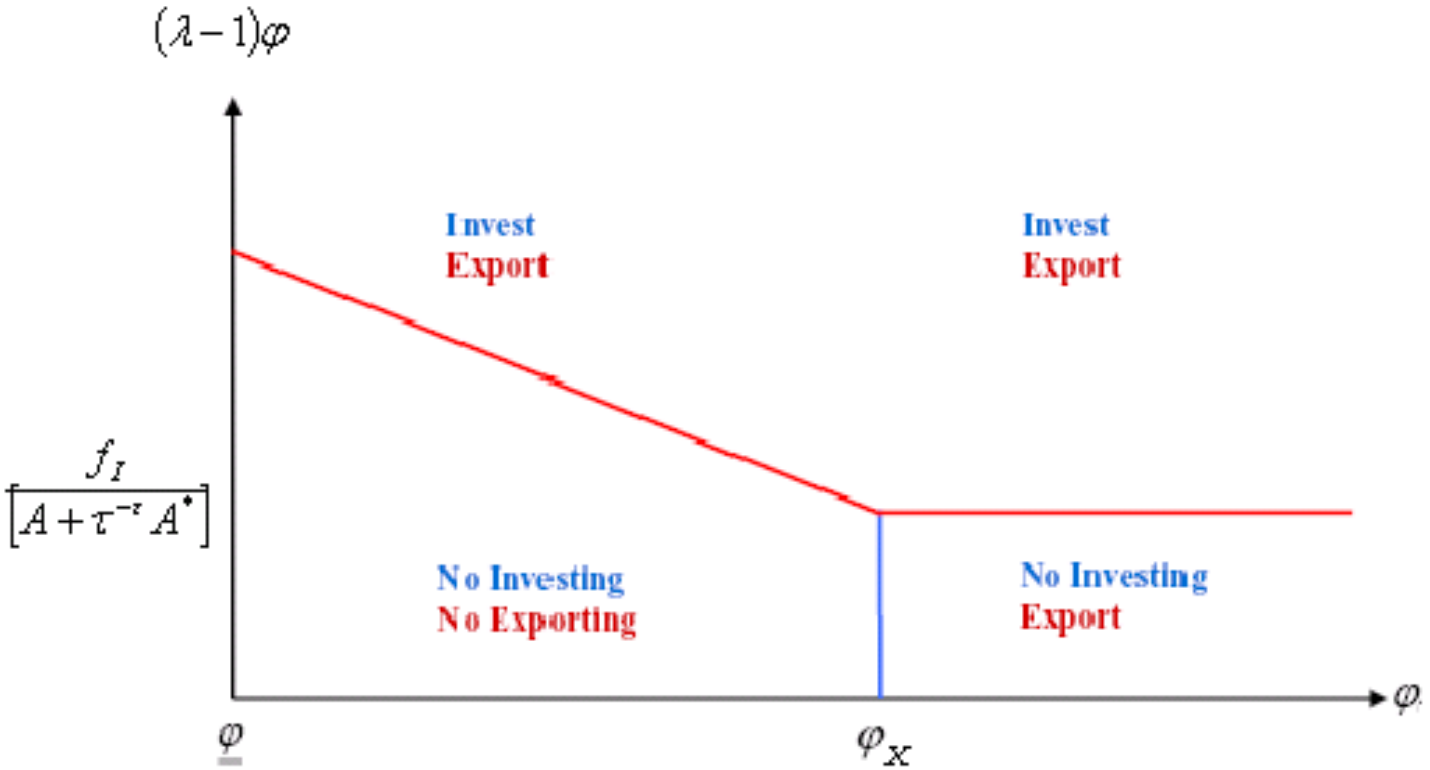
$$\pi_1 = \pi_0$$

- Indifference

$$(\lambda - 1)\varphi = -\varphi \frac{\tau^{-\varepsilon} A^*}{(A + \tau^{-\varepsilon} A^*)} + \frac{f_X + f_I}{(A + \tau^{-\varepsilon} A^*)}$$

Theoretical Underpinnings
Models of exporting and technology investments

Optimal choices of exporting and investing



Adapted from Lieven and Trefler (2007)

Empirical approach: empirical model

- Dynamic model of technology investment with firm-specific heterogeneity

$$\Delta TECH_{it} = \alpha\, TECH_{it-1} + \beta_1 PROD_{it-1} + \beta_2 SIZE_{it} + \beta_3 AGE_{it} + \gamma_1 TRADE_{it} + \gamma_2 FDI_{it} + \gamma_3 OUTSOURCE_{it} + f_i + D_i + e_{it}$$

- $\Delta TECH$ denotes change in technology investment and $TECH_{t-1}$ captures the persistence in technology investment

- *PROD* is productivity and *SIZE* and *AGE* are firm size and age respectively

- *TRADE* is a vector of import/export of services and goods; *FDI* comprises outward and inward FDI; and *OUTSOURCE* contains outsourcing of professional and manual jobs

- *f* denotes time-invariant firm-specific heterogeneity, *D* is a vector of time dummies and *e* is a random error term

Empirical approach: definition of variables

Variable	Definition
Technology investment	The sum of real expenditures on own R&D, computers and software, royalty fees and imports of capital goods.
Knowledge investment	The sum of real expenditures on own R&D, software and royalty fees.
Physical technology investment	The sum of real expenditure on computers and imports of capital goods.
Size	Log of total assets
Capital productivity	Log of sales divided by fixed capital.
Total factor Productivity	Log of total factor productivity estimated based on 3-input (labour, fixed capital and material inputs) production function using the Levinshon-Petrin (2003) technique.
Age	Log of firm age since incorporation.
Services exports	Services exports/total sales
Goods exports	Goods exports/total sales
Services imports	Services imports/total sales
Intermediates imports	Intermediates goods imports/total sales
Indian MNE	Investment by Indian multinationals in their overseas subsidiaries divided by total sales.
Foreign MNE	The share of foreign finance in the firms' total equity.
Outsourcing of professional jobs	The value of outsourced professional jobs divided by total sales.
Outsourcing of manual jobs	The value of outsourced manual jobs divided by total sales.

Empirical approach: estimation method

- The empirical model is estimated with the dynamic panel data estimator due to Blundell and Bond (1998)
- It controls for firm-specific effects and distinguishes true state dependence driving the dynamics of technology investment from unobserved heterogeneity.
- It allows for the endogeneity of the model regressors.
- It estimates simultaneously the model in level and first-differences within a GMM framework (implying that it does not suffer from the problem of weak instruments among other things))

Database description

- Source: Prowess database from the Centre for Monitoring the Indian Economy.
- It covers publicly listed and unlisted firms from a wide cross-section of manufacturing, services, utilities, and financial industries.
- These companies account for more than 70% of industrial output.
- This study focuses on two highly-globalised sectors: software services and pharmaceutical industry.
- Period of analysis:1997-2007

Sample characteristics

Table 1.Frequency distribution of firms

	Software industry				Pharmaceutical industry			
year	Non-MNEs	Indian MNEs	Foreign MNEs	Total	Non-MNEs	Indian MNEs	Foreign MNEs	Total
1997	112	1	8	121	217	1	25	243
1998	131	1	9	141	221	2	25	248
1999	211	2	12	225	238	2	27	267
2000	263	21	18	302	253	4	29	286
2001	245	55	21	321	223	20	31	274
2002	235	90	27	352	212	25	29	266
2003	285	91	30	406	243	29	26	298
2004	319	93	32	444	260	31	27	318
2005	263	106	28	397	236	33	27	296
2006	223	90	46	359	204	38	37	279
2007	154	87	47	288	152	36	34	222
Total	2,441	637	278	3,356	2,459	221	317	2,997

Sample characteristics

Table 2. Summary statistics of main variables of interest

Variable	Software industry				Pharmaceutical industry			
	1997-2000		2001-2007		1997-2000		2001-2007	
	mean	Std dev.	mean	Std dev.	mean	Std dev.	mean	Std dev.
Growth in technology investment	0.052	0.614	0.104	0.611	0.014	0.488	0.074	0.448
Log of technology investment	0.343	0.769	0.537	1.034	0.439	0.833	0.626	1.168
Total factor productivity	-2.958	1.466	-3.026	1.614	-4.205	0.928	-3.73	1.115
Capital productivity	-0.115	1.61	-0.257	1.708	0.288	1.43	0.221	1.488
Size	2.541	1.681	2.549	2.138	3.334	1.485	3.297	1.9
Log of age	1.992	0.706	2.266	0.671	2.701	0.806	2.937	0.705

Sample characteristics

Table 3. Growth of technology investment:
Premia to exporters, importers, multinational and outsourcers

Group	**Software industry**	**Pharmaceutical industry**
Services exporters	0.396***	0.425***
Goods exporters	0.099***	0.452***
Services importers	0.413***	0.444***
Goods importers	0.273***	0.473***
Indian multinationals	0.364***	0.430***
Foreign multinationals	0.274***	0.256***
Outsourcers of professional jobs	0.250***	0.146***
Outsourcers of manual jobs	0.024	0.132***
Total observations	2536	2382

Empirical findings: baseline Model (Table 4)

	Total factor productivity		Capital productivity	
	Software industry	**Pharmaceutical industry**	**Software industry**	**Pharmaceutical industry**
Lagged technology investment	-0.687***	-0.640***	-0.690***	-0.651***
Productivity	-0.021***	0.009***	-0.025***	0.040***
Size	0.215***	0.246***	0.240***	0.242***
Age	0.243***	0.143***	0.240***	0.147***
Services exports	0.048***	0.370***	0.041***	0.432***
Goods exports	0.164***	0.111***	0.176***	0.140***
Services imports	-0.023***	0.876***	-0.012***	0.954***
Intermediates imports	-0.060***	-0.572***	0.081***	-0.692***
Indian multinationals	0.001***	0.150***	0.001***	0.163***
Foreign multinationals	-0.223***	0.530***	-0.211***	0.437***
Outsourcing of professional jobs	0.124***	-0.006***	0.142***	0.009***
Outsourcing of manual jobs	-0.876***	0.436***	-0.811***	0.361***
Total observations	2535	2380	2535	2382
Number of firms	594	454	594	454
Sargan test (p-value)	0.191	0.118	0.677	0.710
Serial correlation test (p-value)	0.940	0.926	0.628	0.597

Empirical findings

1. A 10 percentage points change in the intensity of goods exports would induce firms to increase their rate of technology investment by 1.11 to 1.76 percentage points (Table 4).
2. Service exports also enhance the process of technology upgrading, especially for pharmaceutical firms (Table 4).
3. The technology enhancing effects of goods exports are more pronounced among Indian MNEs (Table 5).
4. Foreign pharmaceutical MNEs' services exports are associated with less technology investment (Table 5).
5. Imports of services are substitutes for technology investment in software industry especially for foreign MNEs (Table 5).
6. Important complementarity between imports of intermediate goods and technology investment for pharma firms (Table 5).

Empirical findings

7. For software firms, the higher the share of foreign MNEs, the lower the rate of technology investment (Table 5).
8. For pharma firms, positive relationship between amount of outward FDI and technology investment at home (Table 5).
9. Outsourcing of professional jobs has beneficial effects, especially in the case of software services (Table 5).
10. Significant positive (negative) relationship between the share of foreign MNEs in pharma industry and knowledge (physical technology) investment (Tables 6 & 7).
11. Faster convergence rate in the investment of physical technology compared to knowledge investment (Tables 6 & 7).

Conclusion

The existence of heterogeneous and complicated relationship between choice of production organisation and technology investment has implications for a well-designed technology policy as well theory that seeks to understand the fundamental factors behind firm's firm heterogeneity (and by implication industry dynamics and nations' competitive advantages).