# Relationship between RD, innovation and productivity in emerging economies: CDM model and alternatives

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# Outline

- What is CDM model?
- Relevant stylized facts on R&D, innovation and productivity in CEE/emerging economies
- Alternative to CDM model
- Testing of alternative model
- Policy issues that arise from alternative model

# What is CDM model?

- Proposed originally by Crépon, Duguet and Mairesse (CDM, 1998)
- Tests the relationship among
  - innovation input (mostly, but not limited to, R&D)
  - innovation output (process, product, organizational)
  - productivity levels (sometimes growth rates)
- CDM as framework to look at the black box of the innovation process at the firm level:
- Based on the concept of a 'knowledge production function' (Griliches, 1988)
  - R&D capital stock determine the level of productivity indirectly via its impact on innovation output.
  - CDM model unpacks the relationship between innovation input and productivity by looking at the innovation output

# Empirical evidence on CDM model

- **High income economies:** Results confirm RD-Innovation-Productivity link
  - the marginal effects for innovation intensity are both statistically and economically very significant in all countries *(Benavente 2006; Criscuolo and Haskell, 2003; Griffith et al., 2006; Janz et al., 2004; Jefferson et al. 2006; Loof and Heshmati, 2002, 2006; Mohen et al. 2006; Parisi et al., 2006; Van Leeuwen and Klomp 2006)*
- **Emerging economies:** Results are scarce, less robust and sometimes mixed but those based on innovation survey data do confirm that innovative firms have higher labor productivity than the rest of firms.
  - The majority of papers that confirm the logic of CDM model do not start with R&D but use modified CDM model which starts from broad notion of innovation which includes investment in machinery and equipment
  - Also, they do not use patents or R&D as they are effectively models of innovation intensity – productivity relationship but not R&D – innovation – productivity.
  - Also, 'broad notion of innovation' mixes up R&D with M&E expenditures and thus muddles up the true nature of innovation in emerging economies

# Empirical evidence on CDM model

- **Emerging economies:** Results are scarce, less robust and sometimes mixed:
  - Positive relationship between innovation and firm performance: for Latin America *(Crespi and Pluvia, 2010)*, for Mexico *(De Fuentes et al., 2015)*, for South Korea *(Lee and Kang, 2007)*, Malaysia *(Hegde and Shapira, 2007)*, Taiwan *(Yan Aw et al., 2008)*, and China *(Jefferson et al., 2006)*.
  - Inconclusive relationship between R&D and innovation: positive for Argentina *(Chudnovski et al., 2006, Arza and López, 2010)*, Brazil *(Correa et al., 2005; Raffo et al., 2008)*, Bulgaria *(Stoevsky, 2005)*; negative or insignificant for Chile *(Benavente, 2006; Benavente and Bravo, 2009)* and Mexico *(Pérez et al., 2005)*.
  - Inconclusive results on innovation – productivity link: positive for Brazil and Mexico and negative for Argentina *(Raffo et al., 2008)*, insignificant effect for Argentina *(Perez et al., 2005)* and Mexico *(Chudnovsky et al., 2006, Benavente, 2006)*.

# Our contribution

- Clarify the relevance of R&D based CDM model in the context of the emerging economies of Euro-Asia (CEE/CIS/Turkey) and test two alternative models

# Some empirical evidence in support of alternative –two way – innovation model

- Innovation in CEE economies is dominated by tangible assets (investment in M&E)
- Productivity at macro levels seems to be strongly driven by production capability (Kravtsova and Radosevic, 2006)
- Innovation in emerging economies is about successful adoption of given technology and much less about new technology driven by own R&D
- Which innovation – productivity model can capture these stylised facts?

# ‘Two way’ and R&D based CDM model tested

- CDM R&D based model: R&D – Patents – Innovation - Productivity
- Two way model: Investment / Production capability – Innovation - Productivity


- BEEPS V database
- Sample 1485 firms, 19 countries, 2012-14

# Descriptive statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| New products/services introduced over the last 3 years | 1,485 | 0.315 | 0.465 | 0 | 1 |
| New production/supply methods introduced over the last 3 years | 1,485 | 0.308 | 0.462 | 0 | 1 |
| New organisational/management practices or structures introduced over the last 3 years | 1,485 | 0.321 | 0.467 | 0 | 1 |
| Applied/Granted a patent/trademark over the last 3 years | 1,484 | 0.079 | 0.270 | 0 | 1 |
| Annual sales accounted for by new or significantly improved products/services >1% | 1,485 | 0.292 | 0.455 | 0 | 1 |
| Expenditures for R&D to annual sales ratio >1% | 1,485 | 0.062 | 0.241 | 0 | 1 |
| Involvement of employees in R&D | 1,485 | 0.229 | 0.420 | 0 | 1 |
| Share of Full-time employees received formal training in last year >1% | 1,485 | 0.083 | 0.247 | 0 | 1 |
| Sales adjusted for national exchange rate per employee (Productivity) | 1,483 | 10.399 | 1.625 | 0 | 20.141 |
| Net book value of machinery vehicles and equipment in the last fiscal year adjusted by national currency exchange rate per full time-employment (capital to labour ratio) | 460 | 14.023 | 4.495 | 0.0099 | 27.328 |
| No. permanent, full-time employees of firm at the end of last fiscal year, logarithm | 1,485 | 3.256 | 1.270 | 0 | 8.343 |
| Age | 1,485 | 13.670 | 10.818 | 1 | 89 |
| Export to total sales ratio >10% | 1,485 | 0.084 | 0.230 | 0 | 1 |
| Share of foreign ownership >10% | 1,485 | 0.056 | 0.216 | 0 | 1 |
| Share of total annual expenditure for purchases of equipment in annual sales in the last fiscal (Investment intensity) | 1,485 | 0.083 | 0.148 | 0 | .99 |

Probability of being an R&D performer is determined only by size of the firm as measured by a number of employees. None of the other variables is significant except investment intensity and age for organisational innovators and export for process innovators.

| Dependent variable: performing R&D | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| VARIABLES | Innovators | Organizational Innovators | Product Innovators | Process Innovators |
| Size (ln # of employees) | 0.0485*** | 0.0660*** | 0.0293*** | 0.0562*** |
| | (0.0113) | (0.0104) | (0.0106) | (0.0103) |
| Age | 0.00273 | -0.00524** | 0.00335 | 0.00205 |
| | (0.00236) | (0.00226) | (0.00222) | (0.00220) |
| Export | 0.0119 | 0.00308 | 0.0449 | 0.0613* |
| | (0.0386) | (0.0371) | (0.0355) | (0.0358) |
| Foreign | 0.0194 | 0.0442 | -0.0244 | -0.0334 |
| | (0.0538) | (0.0499) | (0.0493) | (0.0504) |
| Investment intensity | -0.122 | -0.255*** | 0.0228 | 0.0977 |
| | (0.0901) | (0.0992) | (0.0865) | (0.0828) |
| Observations | 1,481 | 1,458 | 1,473 | 1,461 |
| Country FE | + | + | + | + |
| Industry FE | + | + | + | + |
| Sensitivity[a] | 74.09% | 17.34% | 21.77% | 23.18% |
| Specificity[b] | 49.41% | 92.59% | 92.37% | 93.45% |
| Correctly classified[c] | 62.73% | 68.18% | 70.13% | 71.66% |

[a]Sensitivity – is a fraction of innovators (firms introduced a respective type of innovations) that are correctly identified

[b]Specificity – is a fraction of non-innovators (firms which did not introduce a respective type of innovations) that are correctly identified

[c]Correctly classified – is a fraction of correctly identified innovators and non-innovators

# R&D intensity is positively correlated to Involvement of employees in R&D and Export

| VARIABLES | (1) Innovators | (2) Organizational Innovators | (3) Product Innovators | (4) Process Innovators |
|---|---|---|---|---|
| Size (ln # of employees) | 0.00240 | 0.00161 | 0.00884 | 0.00209 |
| | (0.0103) | (0.0113) | (0.0132) | (0.0115) |
| Age | -0.000289 | -0.000127 | -0.00104 | -0.000650 |
| | (0.00204) | (0.00218) | (0.00283) | (0.00223) |
| Export | 0.0890*** | 0.0847*** | 0.111*** | 0.0980*** |
| | (0.0322) | (0.0317) | (0.0400) | (0.0337) |
| Foreign | 0.0256 | 0.00588 | -0.0191 | -0.00699 |
| | (0.0393) | (0.0377) | (0.0542) | (0.0461) |
| Investment intensity | 0.240** | 0.359*** | 0.184 | 0.136* |
| | (0.111) | (0.124) | (0.151) | (0.0790) |
| Involvement of employees | 0.115*** | 0.121*** | 0.182*** | 0.129*** |
| in R&D | (0.0425) | (0.0430) | (0.0555) | (0.0443) |
| Observations | 642 | 631 | 418 | 568 |
| Country FE | + | + | + | + |
| Industry FE | + | + | + | + |
| Sensitivity[a] | 8.33% | 12.28% | 13.46% | 10.71% |
| Specificity[b] | 99.48% | 99.30% | 98.91% | 99.41% |
| Correctly classified[c] | 90.97% | 91.44% | 88.28% | 90.67% |

[a]Sensitivity – is a fraction of firms with expenditures for R&D to annual sales ratio >1% that are correctly identified

[b]Specifity – is a fraction of firms with expenditures for R&D to annual sales ratio <1% that are correctly identified

[c]Correctly classified – is a fraction of correctly identified firms

In simple model, predicted R&D intensity is significant for organizational and process innovators and for pooled regression with all types of innovators.
In extended model, predicted R&D intensity keeps significance for organizational innovators and the pooled regression with all types of innovators.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| VARIABLES | Innovators | | Organizational Innovators | | Product Innovators | | Process Innovators | |
| Predicted R&D intensity | 0.0686*** | 0.0473* | 0.0647*** | 0.0496* | 0.0188 | -0.0298 | 0.0759*** | 0.0352 |
| | (0.0243) | (0.0280) | (0.0235) | (0.0271) | (0.0260) | (0.0287) | (0.0267) | (0.0304) |
| Age | | 0.00262* | | 0.00267* | | 0.00273* | | 0.00269* |
| | | (0.00141) | | (0.00140) | | (0.00141) | | (0.00141) |
| Export | | 0.0326 | | 0.0337 | | 0.0518** | | 0.0354 |
| | | (0.0236) | | (0.0233) | | (0.0240) | | (0.0239) |
| Foreign | | 0.0486* | | 0.0481* | | 0.0478* | | 0.0508* |
| | | (0.0273) | | (0.0274) | | (0.0274) | | (0.0274) |
| Investment intensity | | -0.120 | | -0.128* | | -0.0595 | | -0.0928 |
| | | (0.0737) | | (0.0745) | | (0.0697) | | (0.0698) |
| Involvement of employees in R&D | | 0.0917*** | | 0.0907*** | | 0.111*** | | 0.0925*** |
| | | (0.0244) | | (0.0243) | | (0.0252) | | (0.0251) |
| Observations | 1,386 | 1,382 | 1,386 | 1,382 | 1,386 | 1,382 | 1,386 | 1,382 |
| Country FE | + | + | + | + | + | + | + | + |
| Industry FE | + | + | + | + | + | + | + | + |
| Sensitivity[a] | 3.65% | 5.88% | 4.38% | 5.88% | 4.38% | 5.15% | 2.92% | 5.15% |
| Specificity[b] | 99.84% | 99.60% | 99.84% | 99.60% | 99.84% | 99.52% | 99.92% | 99.60% |
| Correctly classified[c] | 90.33% | 90.38% | 90.40% | 90.38% | 90.40% | 90.23% | 90.33% | 90.30% |

[a]Sensitivity – is a fraction of firms which have patents (either applied or granted) that are correctly identified

[b]Specifity – is a fraction of firms without patents that are correctly identified

[c]Correctly classified – is a fraction of correctly identified firms with and without patents

## A poor explanatory power of the original (R&D based) CDM model:

1) Determinants of R&D are positively correlated to involvement of employees in R&D and Export (not to size, age, FDI)

2) Predicted R&D intensity significantly and positively affects patent activity only for organizational innovators and the pooled regression

3) But predicted patents cannot explain productivity once we control for other factors

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| VARIABLES | Innovators | | Organizational Innovators | | Product Innovators | | Process Innovators | |
| Predicted patent | 0.468*** | 0.174 | 0.393*** | 0.0943 | 0.462*** | 0.182 | 0.330*** | -0.00254 |
| | (0.111) | (0.129) | (0.111) | (0.128) | (0.111) | (0.128) | (0.111) | (0.129) |
| Age | | -0.00359 | | -0.00285 | | -0.00388 | | -0.00167 |
| | | (0.00651) | | (0.00655) | | (0.00654) | | (0.00654) |
| Export | | 0.135 | | 0.147 | | 0.131 | | 0.163 |
| | | (0.114) | | (0.114) | | (0.114) | | (0.114) |
| Foreign | | 0.420*** | | 0.440*** | | 0.422*** | | 0.463*** |
| | | (0.150) | | (0.150) | | (0.150) | | (0.150) |
| Investment intensity | | -2.534*** | | -2.554*** | | -2.536*** | | -2.570*** |
| | | (0.261) | | (0.260) | | (0.260) | | (0.260) |
| Involvement of employees in R&D | | 0.240* | | 0.281** | | 0.241** | | 0.328*** |
| | | (0.123) | | (0.122) | | (0.122) | | (0.123) |
| Constant | 8.699*** | 8.974*** | 8.777*** | 9.015*** | 8.689*** | 8.964*** | 8.814*** | 9.049*** |
| | (0.495) | (0.468) | (0.495) | (0.467) | (0.496) | (0.469) | (0.496) | (0.468) |
| Country FE | + | + | + | + | + | + | + | + |
| Industry FE | + | + | + | + | + | + | + | + |
| Observations | 1,483 | 1,483 | 1,483 | 1,483 | 1,483 | 1,483 | 1,483 | 1,483 |
| Adjusted $R^2$ | 0.2212 | 0.2819 | 0.2183 | 0.2813 | 0.2208 | 0.2820 | 0.2163 | 0.2810 |

# Interim conclusion

- A poor explanatory power of the original (R&D based) CDM model determines the need for alternative model which would recognise the significant stylized facts of innovation in emerging economies
  - The importance of physical investment in innovation
  - The role of production capability

# Alternative investment-driven model

- 1st regression: determinants of investment intensity
- 2nd regression: determinants of innovation intensity
  - Production capability variables include additional determinants of innovation intensity (internationally recognized certificates, new logistical or business support, new organizational/ management practices and employee training)
- 3rd regression: determinants of productivity

# Determinant of investment intensity is size. Larger firms have smaller investment intensity

| | (1) | (2) |
|---|---|---|
| VARIABLES | | |
| Size (ln # of employees) | -0.0594*** | -0.0669*** |
| | (0.0183) | (0.0205) |
| Export | -0.0247 | -0.00356 |
| | (0.0528) | (0.0655) |
| Capital to labor (log) | 0.00670 | 0.0112 |
| | (0.00539) | (0.00995) |
| Age | 0.000477 | 0.00170 |
| | (0.00182) | (0.00182) |
| Foreign | 0.0198 | -0.00366 |
| | (0.0818) | (0.0837) |
| Observations | 460 | 458 |
| Country FE | - | + |
| Industry FE | - | + |
| Sensitivity [a] | 25,51% | 46,15% |
| Specificity [b] | 84,09% | 79,09% |
| Correctly classified [c] | 59,13% | 65,07% |

[a] Sensitivity – is a fraction of firms with high investment intensity that are correctly identified

[b] Specificity – is a fraction of firms with low investment intensity that are correctly identified

[c] Correctly classified – is a fraction of correctly identified firms with low and high investment intensity

Results show that there is a negative statistically significant impact of size on investment intensity.

None of the other control variables is significant.

Results improve once we control for country and industry fixed effects.

# Innovation intensity is negatively related with Investment intensity, it's positively driven by R&D intensity, involvement of employees in R&D and by Production Capability (New logistics, Employee training, New management practices)

| | (1) | (2) | (3) |
|---|---|---|---|
| VARIABLES | | | |
| Predicted Investment intensity | -0.00945 | -0.00611 | -0.0105 |
| | (0.0427) | (0.0426) | (0.0415) |
| Share of expenditures | 0.351*** | 0.329*** | 0.263*** |
| for R&D (dummy) | (0.0446) | (0.0447) | (0.0444) |
| Involvement of employees in R&D dummy | 0.224*** | 0.169*** | 0.124*** |
| | (0.0325) | (0.0348) | (0.0343) |
| Internationally-recognized certification dummy | | 0.0391 | 0.0203 |
| | | (0.0281) | (0.0275) |
| New logistical or business support | | 0.162*** | 0.0758* |
| | | (0.0400) | (0.0403) |
| Employee training dummy | | 0.0701* | 0.0476 |
| | | (0.0363) | (0.0354) |
| New organizational /management practices | | | 0.187*** |
| dummy | | | (0.0225) |
| Observations | 1,475 | 1,475 | 1,475 |
| Country FE | + | + | + |
| Industry FE | + | + | + |
| Sensitivity [a] | 30.95% | 31.64% | 40.88% |
| Specificity [b] | 93.09% | 93.09% | 91.46% |
| Correctly classified [c] | 74.85% | 75.05% | 76.61% |

[a] Sensitivity – is a fraction of firm with % annual sales of new/significantly improved products >1% that are correctly identified

[b] Specificity – is a fraction of firms with % annual sales of new/significantly improved products <1% that are correctly identified

[c] Correctly classified – is a fraction of correctly identified firms

Empirical results of the alternative model:

1) Larger firms have smaller investment intensity. Export, age, capital intensity and FDI do not matter.

2) Innovation intensity is positively driven by R&D intensity, involvement of employees in R&D. and by Production Capability (New logistics, Employee training, New management practices)

3) Determinants of productivity including capital intensity (only 460 observations)

Productivity IS explained by production capability;

Innovative intensity does NOT affect productivity.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| VARIABLES | | | | | |
| Predicted Innovative intensity | 0.194 | 0.0204 | 0.150 | 0.0688 | 0.211** |
| | (0.134) | (0.0909) | (0.0956) | (0.0870) | (0.0912) |
| Granted patents over the last 3 | 0.143 | 0.540*** | 0.512*** | 0.491*** | 0.442*** |
| years | (0.203) | (0.161) | (0.159) | (0.150) | (0.147) |
| Size (ln # of employees) | | -0.0373 | 0.0189 | -0.0200 | 0.0332 |
| | | (0.0350) | (0.0354) | (0.0329) | (0.0332) |
| Capital to labor (log) | -0.0302** | | | | |
| | (0.0141) | | | | |
| Production capability (certificates + | 0.470*** | 0.192* | 0.263** | 0.0584 | 0.131 |
| employee training) | (0.132) | (0.101) | (0.103) | (0.0956) | (0.0966) |
| Constant | 10.24*** | 10.42*** | 9.466*** | 9.140*** | 8.767*** |
| | (0.225) | (0.118) | (0.346) | (0.400) | (0.500) |
| Country FE | - | - | - | + | + |
| Industry FE | - | - | + | - | + |
| Observations | 460 | 1,482 | 1,482 | 1,482 | 1,482 |
| Adjusted $R^2$ | 0.0428 | 0.0087 | 0.0663 | 0.1703 | 0.2236 |

# Alternative production capability driven model

- 1st regression: determinants of production capability
- 2nd regression: determinants of innovation intensity
- 3rd regression: determinants of productivity

# Production capability is positively driven by size, export and age, while investment intensity is insignificant

| VARIABLES | (1)<br>Production capability |
|---|---|
| Size (ln # of employees) | 0.0602*** |
| | (0.00889) |
| Age | 0.00546*** |
| | (0.00192) |
| Export | 0.0616** |
| | (0.0306) |
| Foreign | 0.00216 |
| | (0.0401) |
| Investment intensity | 0.00343 |
| | (0.0737) |
| Observations | 1,476 |
| Country FE | + |
| Industry FE | + |
| Sensitivity [a] | 39.90% |
| Specificity [b] | 91.21% |
| Correctly classified [c] | 77.10% |

[a] Sensitivity – is a fraction of firms which have certificates and employee training that are correctly identified

[b] Specificity – is a fraction of firms which do not have certificates and employee training that are correctly identified

[c] Correctly classified – is a fraction of correctly identified firms with and without certificates and employee training

Innovation intensity is positively driven by R&D intensity, and by predicted production capability but at a low level of significance.
Patent intensity is positively driven by R&D intensity but not by production capability.

| VARIABLES | (1) Innovation intensity | (2) Patents |
|---|---|---|
| Predicted production capability (certificates + employee training) | 0.0798* | 0.0284 |
| | (0.0421) | (0.0259) |
| Share of expenditures for R&D dummy | 0.386*** | 0.154*** |
| | (0.0449) | (0.0212) |
| Size (ln # of employees) | 0.0140 | 0.0281*** |
| | (0.0116) | (0.00719) |
| Age | 0.00164 | 0.000846 |
| | (0.00214) | (0.00143) |
| Export | 0.0160 | 0.00860 |
| | (0.0357) | (0.0214) |
| Foreign | -0.0626 | 0.0236 |
| | (0.0476) | (0.0258) |
| Investment intensity | -0.0181 | -0.0278 |
| | (0.0867) | (0.0603) |
| Observations | 1,471 | 1,330 |
| Country FE | + | + |
| Industry FE | + | + |
| Sensitivity [a] | 26.28% | 13.68% |
| Specificity [b] | 95.29% | 99.26% |
| Correctly classified [c] | 75.12% | 91.73% |

[a] Sensitivity – is a fraction of firm with % annual sales of new/significantly improved products >1% that are correctly identified

[b] Specificity – is a fraction of firms with % annual sales of new/significantly improved products <1% that are correctly identified

[c] Correctly classified – is a fraction of correctly identified firms

Neither predicted innovation intensity nor patent intensity can explain productivity improvements.

However, in seven out of eight regressions, production capability variable is a highly significant explanatory factor of productivity.

| VARIABLES | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Predicted innovation intensity (from Equation with Dependent - Innovation intensity) | 0.288 | 0.623 | 0.0154 | 0.253 | | | | |
| | (0.350) | (0.404) | (0.385) | (0.482) | | | | |
| Predicted innovation intensity (from Equation with Dependent Patents) | | | | | 0.00440 | 0.533 | 0.408 | 0.659 |
| | | | | | (0.437) | (0.525) | (0.450) | (0.556) |
| Capital to labor (ln) | -0.0170 | -0.0212 | 0.00615 | -0.00150 | -0.0189 | -0.0233 | 0.00827 | -0.000301 |
| | (0.0144) | (0.0145) | (0.0267) | (0.0273) | (0.0143) | (0.0145) | (0.0267) | (0.0274) |
| Predicted production capability (certificates + employee training) | 0.737*** | 0.464** | 0.490*** | 0.238 | 0.783*** | 0.524*** | 0.431** | 0.195 |
| | (0.179) | (0.202) | (0.182) | (0.210) | (0.168) | (0.197) | (0.174) | (0.209) |
| Constant | 9.724*** | 10.77*** | 8.897*** | 10.17*** | 9.822*** | 11.74*** | 8.802*** | 9.661*** |
| | (0.276) | (1.353) | (0.710) | (1.495) | (0.265) | (1.346) | (0.708) | (1.495) |
| Country FE | - | - | + | + | - | - | + | + |
| Industry FE | - | + | - | + | - | + | - | + |
| Observations | 456 | 456 | 456 | 456 | 447 | 447 | 447 | 447 |
| Adjusted $R^2$ | 0.0515 | 0.0823 | 0.1621 | 0.1674 | 0.0520 | 0.0772 | 0.1609 | 0.1643 |

# Robustness check – 1

1) Traditional model: predicted patent intensity is not significant in any of subgroups and overall
2) Alternative investment-driven model shows that predicted production capability is the only significant variable
3) Alternative production capability driven model confirms the important of production capabilities

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Industry FE NOT included | | | | Industry FE included | | | |
| VARIABLES | Common sample | Lower Income | Upper Middle Income | High Income | Common sample | Lower Income | Upper Middle Income | High Income |
| Predicted innovation intensity (from Equation with Dependent Innovation intensity) | 0.288 | -0.825 | 0.539 | 0.639 | 0.623 | -0.321 | 0.806* | -0.0708 |
| | (0.350) | (1.484) | (0.350) | (0.554) | (0.404) | (2.488) | (0.414) | (0.760) |
| Capital to labor (ln) | -0.0170 | -0.0214 | 0.0274 | 0.123*** | -0.0212 | -0.0207 | 0.0174 | 0.124*** |
| | (0.0144) | (0.0458) | (0.0222) | (0.0396) | (0.0145) | (0.0524) | (0.0219) | (0.0369) |
| Predicted production capability (certificates + employee training) | 0.737*** | 1.410** | 0.460** | -1.008* | 0.464** | 1.252 | 0.274 | -0.834 |
| | (0.179) | (0.566) | (0.200) | (0.564) | (0.202) | (0.824) | (0.220) | (0.647) |
| Constant | 9.724*** | 9.352*** | 9.192*** | 10.44*** | 10.77*** | 8.882*** | 10.95*** | 11.55*** |
| | (0.276) | (0.982) | (0.391) | (0.686) | (1.353) | (2.205) | (1.183) | (0.937) |
| Country FE | - | - | - | - | - | - | - | - |
| Industry FE | - | - | - | - | + | + | + | + |
| Observations | 456 | 64 | 303 | 67 | 456 | 64 | 303 | 67 |
| Adjusted $R^2$ | 0.0515 | 0.0495 | 0.0296 | 0.1468 | 0.0823 | 0.0000 | 0.1201 | 0.3643 |

# Robustness check – 2

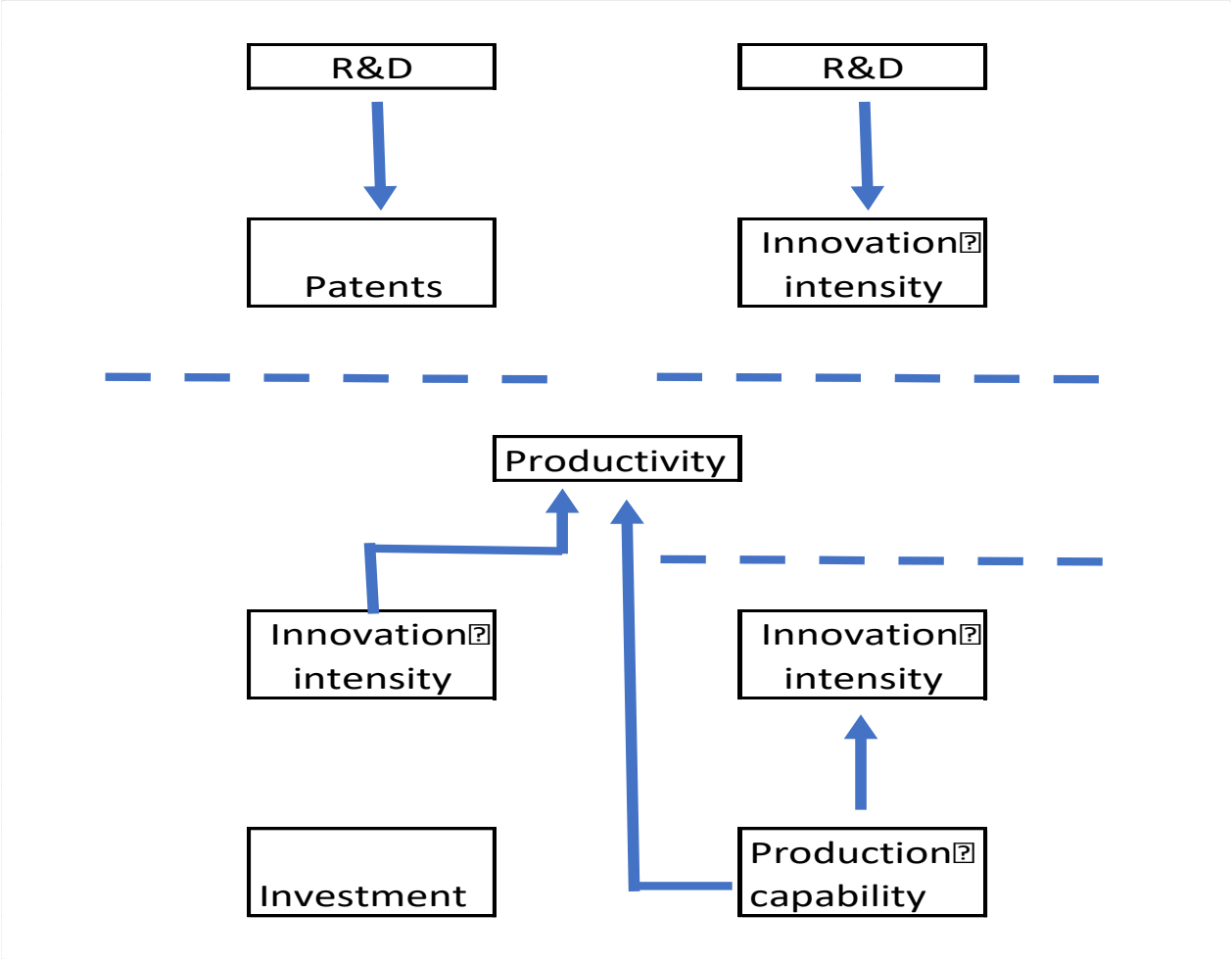
1) Traditional CDM model: predicted innovation intensity measured by patents is essential but only in high tech sectors
2) Investment-driven model: predicted production capability is a significant determinant of productivity in both technology groups. Capital intensity is significant and negative, confirming that even in emerging economies, productivity is much less about capital and equipment.
3) Production capability driven model broadly supports the importance of production capability in explaining productivity

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | Country and Industry FE NOT included | | | Country FE included | | | Country and Industry FE included | | |
| VARIABLES | Common sample | Low tech | High tech | Common sample | Low tech | High tech | Common sample | Low tech | High tech |
| Predicted innovation intensity (from Equation with Innovation intensity) | 0.288 | -0.659 | 0.227 | 0.0154 | -0.936 | 0.553 | 0.253 | -0.384 | 0.674 |
| | (0.350) | (0.510) | (0.382) | (0.385) | (0.614) | (0.373) | (0.482) | (0.754) | (0.439) |
| Capital to labor (ln) | -0.0170 | -0.0136 | -0.0567** | 0.00615 | 0.0128 | 0.0668 | -0.00150 | 0.00246 | 0.0650 |
| | (0.0144) | (0.0170) | (0.0244) | (0.0267) | (0.0319) | (0.0414) | (0.0273) | (0.0330) | (0.0425) |
| Predicted production capability (certificates + employee training) | 0.737*** | 0.856*** | 0.635* | 0.490*** | 0.531** | 0.159 | 0.238 | 0.255 | 0.130 |
| | (0.179) | (0.206) | (0.339) | (0.182) | (0.205) | (0.353) | (0.210) | (0.243) | (0.372) |
| Constant | 9.724*** | 9.857*** | 10.44*** | 8.897*** | 8.740*** | 7.465*** | 10.17*** | 9.996*** | 8.379*** |
| | (0.276) | (0.323) | (0.516) | (0.710) | (0.829) | (1.196) | (1.495) | (1.573) | (1.646) |
| Country FE | - | - | - | + | + | + | + | + | + |
| Industry FE | - | - | - | - | - | - | + | + | + |
| Observations | 456 | 281 | 164 | 456 | 281 | 164 | 456 | 281 | 164 |
| Adjusted $R^2$ | 0.0515 | 0.0569 | 0.0466 | 0.1621 | 0.2113 | 0.1769 | 0.1674 | 0.2134 | 0.1535 |

# Summary of results

| | R&D intensity | Patents | Innovation intensity | Productivity |
|---|---|---|---|---|
| **Original CDM model** | Involvement of employees in R&D (sig, +) | Predicted R&D intensity (sig, +/ns)<br>FDI (sig, +)<br>Involvement in R&D (sig,+) | Predicted R&D intensity (sig, +/ns)<br>Involvement in R&D (sig,+) | Predicted patents (ns)<br>Predicted innovative sales (ns)<br>Investment intensity (sig, -)<br>Involvement employees in R&D (sig, +)<br>FDI (sig, +) |
| **Investment driven model** | Investment intensity | Innovation intensity | | Productivity |
| | Size (sig, - ) | Predicted investment intensity (ns)<br>R&D expenditures (sig, +)<br>Involvement of employees in R&D (sig, +)<br>Logistic/business support (sig, +)<br>Management practices (sig, +)<br>Quality certificates (ns) | | Predicted innovation intensity (sig, +)<br>Patents (sig, +)<br>Production capability (sig, +)(ns with FE) |
| **Production driven model** | Production capability | Patents | Innovation intensity | Productivity |
| | Size (sig, +)<br>Export (sig, +) | Predicted production capability (ns)<br>R&D exp. (sig, +)<br>Size (sig, +) | Predicted production capability (sig, +)<br>R&D exp. (sig, +)<br>Size (ns) | Predicted innovation intensity (ns)<br>Predicted patents (ns)<br>Predicted production capability (sig, +) |

# Summary of significant linkages in CDM and alternative models



# Conclusions I

- Use of 'broad' notion of innovation in modified CDM models hides important distinction between intangible and tangible components of innovation and does not take into account production capabilities
- Testing of the original (R&D based) CDM model in BEEPS sample confirms the relevance of our (alternative) hypothesis (cf. predicted innovation intensity does not explain productivity in the emerging economies context)
- **Inclusion of investment and production capability results in two alternative models which better reflects stylized facts of innovation activities**
- Investment-driven model shows that productivity is explained by innovation intensity, patents and production capability factors
- Production capability driven model shows that productivity is firmly and solely explained by production capability
- Production capability and innovation are not linearly related and should be seen as qualitatively different activities
- Innovation and production capability are two different types of capabilities (cf. threshold levels) which has important policy implications

# Conclusion II

- Application of CDM model in its original (R&D based) and modified form gives one sided picture of technology upgrading in emerging economies which does not reflect stylised facts of innovation in emerging economies
- It re-establishes the importance of conventional linear innovation model and hides diversity of patterns of technology upgrading, especially the role of physical investment as ingredient of innovation process, the role of production capability and non-linear relationship between R&D and innovation and production capability
- We hope our paper opens new avenues for exploring the relationship between innovation and productivity in emerging economies

**Thank you for your attention**