

The development of productive structures of EU Member States and sectors

Assessing international competitiveness with the product space
approach

Andreas Reinstaller¹

¹Austrian Institute of Economic Research (WIFO)

January 23rd 2014 / FIW Seminar in International Economics

Overview

1 Questions

2 Data

3 Competitiveness and the product space

- Analysing the country-product network
- Benchmarking countries & products
- Product complexity and competitiveness

4 Development trajectories in the product space

- Analysing the network of products
- Neighbourhood density and competitive advantage
- Product space and economic opportunity

5 Policy implications

6 References

Growth and the export basket

- Economic performance and the composition of the export basket are intrinsically related (Hausmann - Hwang - Rodrik 2007)
- “Richer” countries export higher-quality goods (see also Schott (2004), QJE) → international competition from “below”. “Higher-quality” implies
 - better products in the top segments of unspecific products (produced by many countries), or
 - products produced only by a few (high income) countries, or
 - totally new products (difficult with trade data).
- “Poorer” countries however face the problem on how to get to develop “rich” country products.
- Development and growth imply horizontal and vertical differentiation (Sutton - Treffler 2011)
- Issues for the analysis of competitiveness and development potential of countries:
 - **Quality at the product level is latent: can we capture this from the data?**
 - **How does diversification actually happen?**

Data

- BACI (Base pour l'Analyse du Commerce International) international trade database at the product level by CEPII;
 - Time coverage: 1995-2010
 - Product coverage: HS 6-digit product disaggregation; $p=5109$.
 - Country coverage: $c=232$.
 - Advantages (over COMTRADE): Adjusted bilateral values and quantities of exports (\rightarrow unit values).
 - Disadvantages (of trade data): manufacturing perspective \rightarrow services completely neglected
- For sector analysis:
 - Correspondence tables HS \rightarrow NACE 1.1 & NACE 2;
 - trade share weighted sectoral aggregates for all sector specific indicators calculated from trade data
 - EUKLEMS 1995-2007 for econometric analysis
- Additional filtering of data to reduce noise.

Country product networks and capabilities

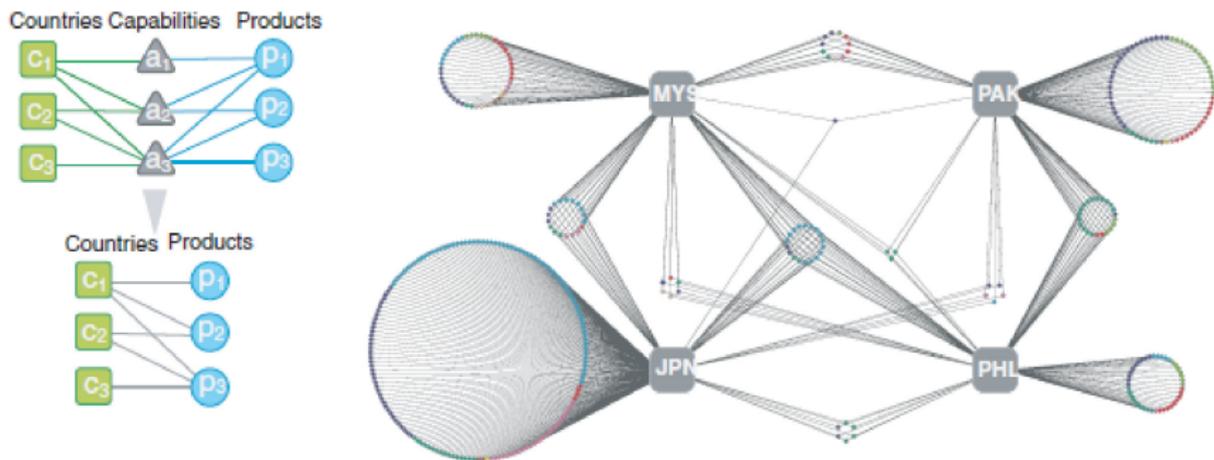
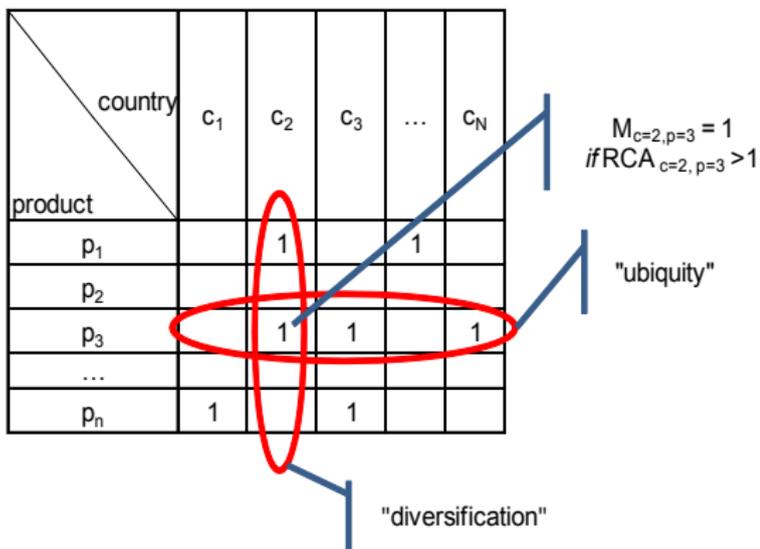


Figure : ex Hidalgo - Hausman (2009), p. 1571

Setting up the bi-partite network

- Network $M_{c,p}$: Connects country c to product p when $RCA > 1$ (entry 1)



Recursive algorithm: Method of reflections

- Explore the network recursively:

$$k_{c,0} = \sum_p M_{c,p} \quad \text{diversification} \quad \rightarrow \quad k_{c,n} = \frac{1}{k_{c,0}} \sum_p M_{c,p} k_{p,n-1} \quad \text{for } n \geq 1$$
$$k_{p,0} = \sum_c M_{c,p} \quad \text{ubiquity} \quad \rightarrow \quad k_{p,n} = \frac{1}{k_{p,0}} \sum_c M_{c,p} k_{c,n-1} \quad \text{for } n \geq 1$$

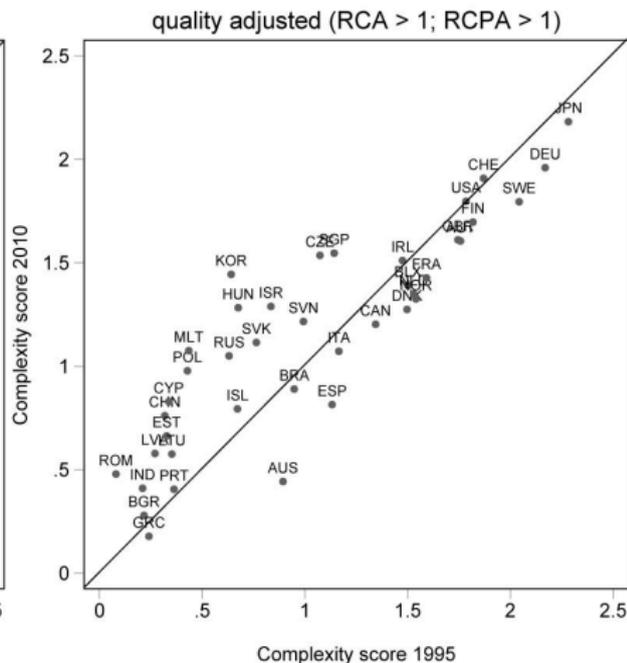
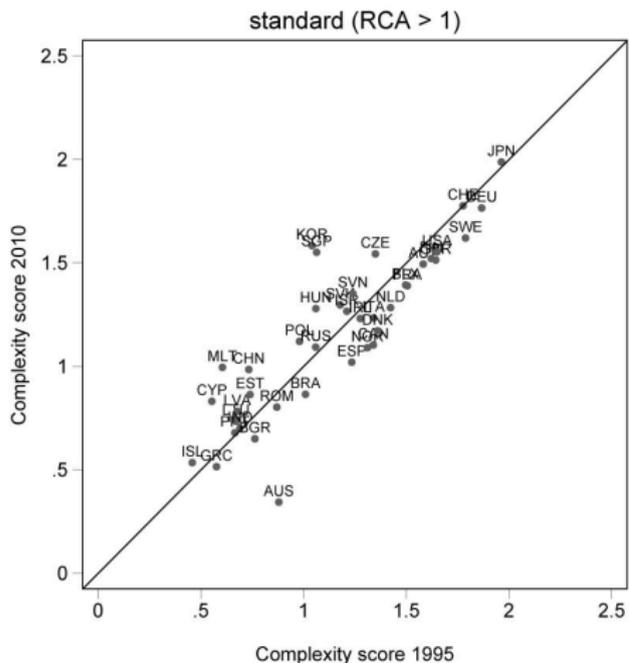
- The method of reflections expresses the properties of a node in a network as a combination of the properties of all its neighbours. Vector $k_c = (k_{c,0}, k_{c,1}, \dots, k_{c,n})$ characterises a country c and $k_p = (k_{p,0}, k_{p,1}, \dots, k_{p,n})$ characterises a product p .
- Economic interpretation: *depth* and *breadth of the knowledge base* of a product/country
- $n \rightarrow$ maximum number of iterations to achieve stable ranking \rightarrow An issue!
- Caldarelli et al (2012) and Tachella (2012) devise a linear fixed point algorithm; rankings change mostly for textiles and clothing (underestimated), and a number of basic commodities/services (overestimated).

Illustration

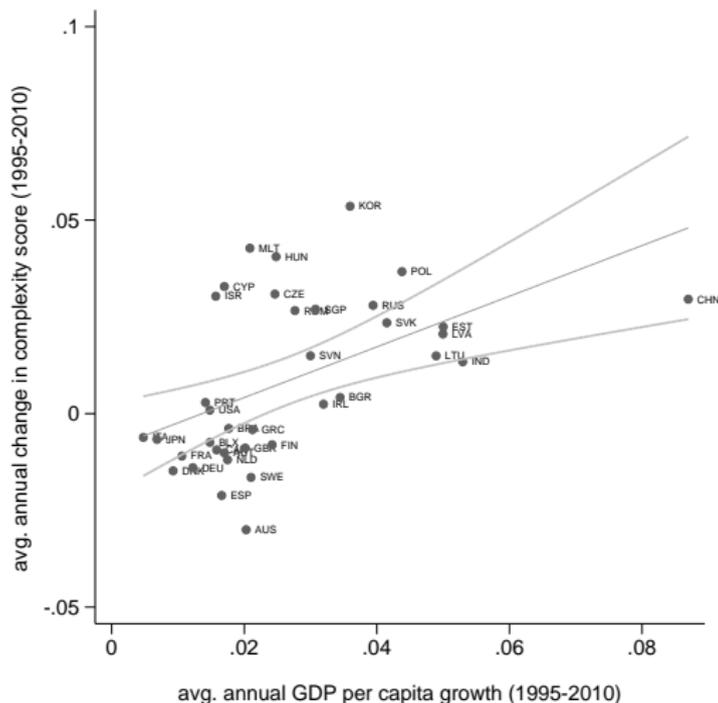
| n | country | product |
|---|--|---|
| 0 | $k_{c,0}$: number of products exported by country c , diversification → "How many products are exported by country c ?" | $k_{p,0}$: number of countries exporting product p , ubiquity → "How many countries export product p ?" |
| 1 | $k_{c,1}$: average ubiquity of products exported by country c → "How common are the products exported by country c ?" | $k_{p,1}$: Average diversification of the countries exporting product p → "How diversified are the countries exporting product p ?" |
| 2 | $k_{c,2}$: Average diversification of countries with a similar export basket as country c → "How diversified are countries exporting similar products as those exported by country c ?" | $k_{p,2}$: Average ubiquity of the products exported by countries exporting product p → "How ubiquitous are the products exported by product p 's exporters?" |

Source: Abdon et al. (2010), p. 8, following Hidalgo - Hausmann (2009), Supplementary material p.8

Standard and quality adjusted complexity scores



Complexity scores and economic growth

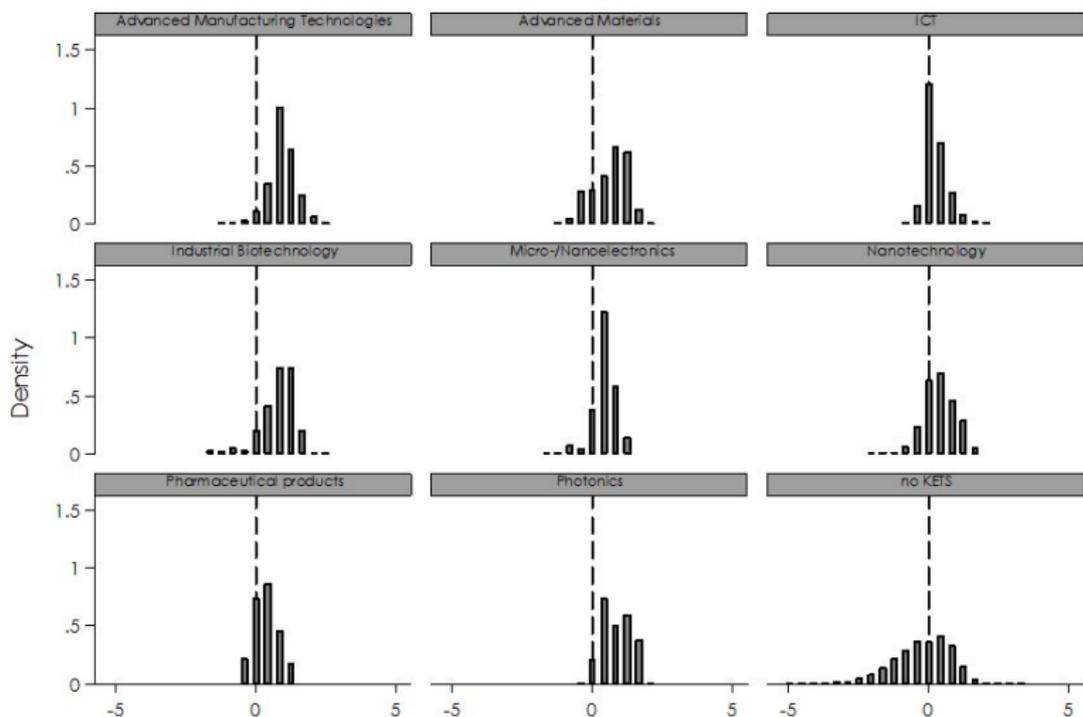


Which capabilities?

| VARIABLE | Factor loadings | | | | | Correlation | | | |
|--|-----------------|-------|-------|-------|-------------|-------------|-------|-------|-------|
| | PC1 | PC2 | PC3 | PC4 | Unexplained | PC1 | PC2 | PC3 | PC4 |
| Government Effectiveness | 0.43 | 0.06 | -0.07 | -0.23 | 0.05 | 0.97 | 0.08 | 0.13 | 0.47 |
| Regulatory quality | 0.40 | 0.19 | -0.03 | -0.21 | 0.11 | 0.91 | 0.24 | 0.20 | 0.39 |
| Rule of Law | 0.42 | 0.06 | -0.05 | -0.31 | 0.05 | 0.96 | 0.06 | 0.15 | 0.40 |
| R&D intensity | 0.38 | -0.25 | 0.02 | 0.02 | 0.20 | 0.81 | -0.32 | 0.19 | 0.61 |
| Researcher intensity | 0.40 | -0.19 | 0.00 | 0.18 | 0.12 | 0.85 | -0.23 | 0.21 | 0.74 |
| Education Expenditures as % of GNI labour force with secondary education (% of total labour force) | 0.30 | 0.02 | 0.00 | -0.04 | 0.56 | 0.66 | 0.02 | 0.17 | 0.40 |
| labour force with tertiary education (% of total labour force) | 0.14 | 0.07 | 0.66 | 0.15 | 0.22 | 0.26 | -0.02 | 0.88 | 0.11 |
| FDI flows in % of GDP | 0.25 | -0.12 | -0.20 | 0.82 | 0.08 | 0.45 | -0.03 | -0.03 | 0.95 |
| Employment in industry (% of total employment) | 0.04 | 0.63 | -0.04 | 0.28 | 0.24 | 0.06 | 0.85 | 0.12 | 0.06 |
| Trade in services (% of GDP) | 0.03 | 0.14 | 0.70 | 0.06 | 0.22 | 0.03 | 0.05 | 0.87 | -0.13 |
| | 0.05 | 0.65 | -0.19 | 0.03 | 0.20 | 0.14 | 0.88 | -0.07 | -0.04 |

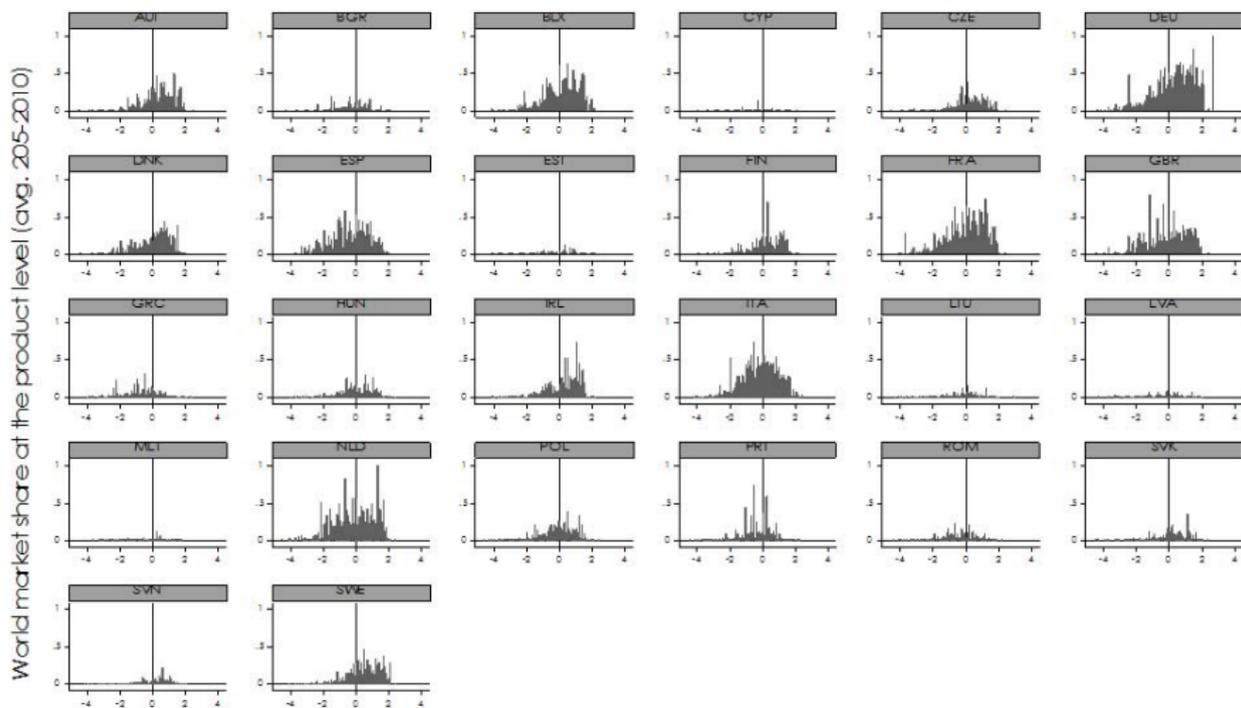
- PC 1: Stage of development indicator combining institutional quality & knowledge intensity (quality of governance, R&D intensity and education expenditures).
- PC 2: Indicator of FDI flows and trade in services.
- PC 3: Industrial base (share of labour force with secondary education in total labour force and employment share in industry).
- PC 4: Tertiary education & quality of governance indicators (share labour force with tertiary education in total labour force).

PCS: KETs, ICT and pharmaceuticals



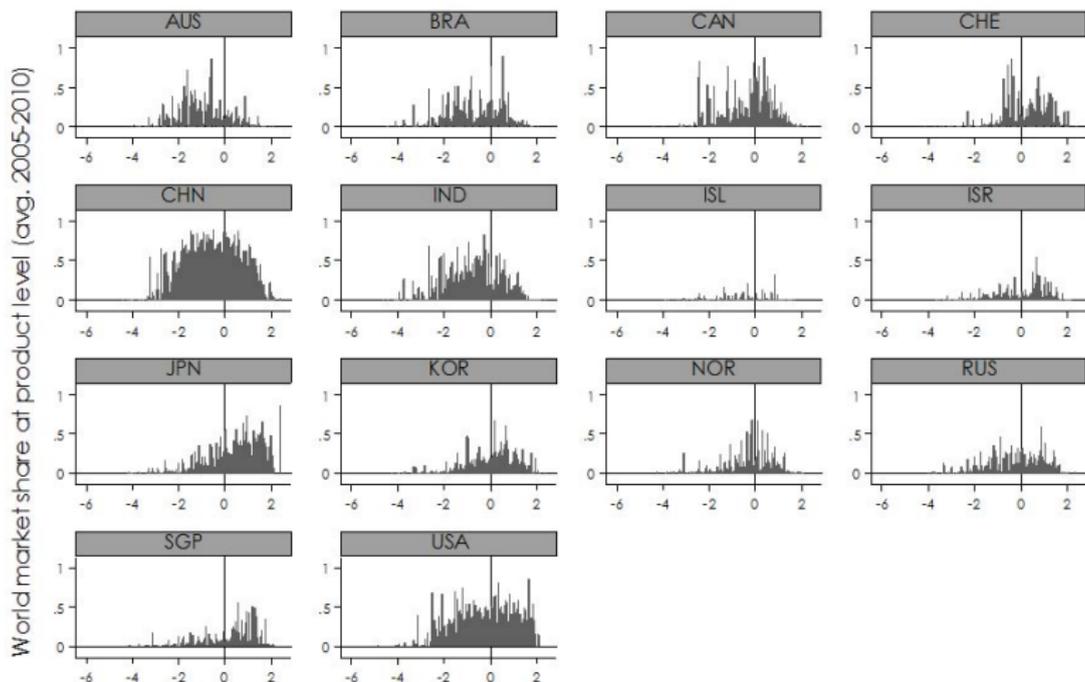
Distribution of product complexity for KETs products

World market shares and complexity: EU



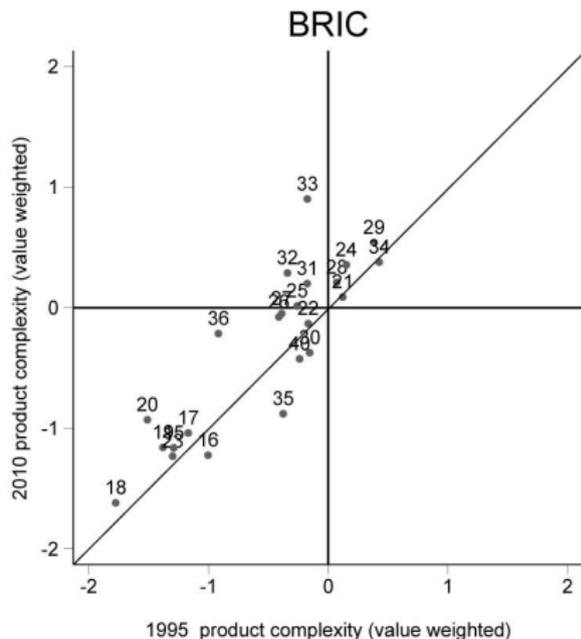
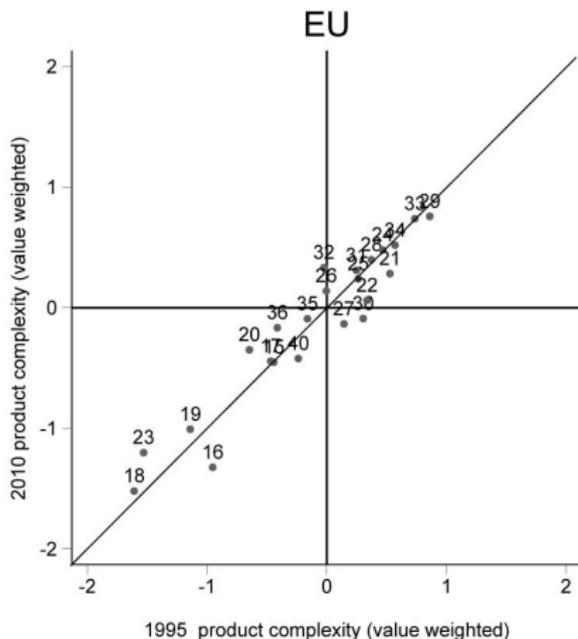
Product complexity (avg. 2005-2010)

World market shares and complexity: Competing countries



Product complexity (avg. 2005-2010)

Development of complexity at the sector level: EU vs BRIC



Sector performance and product complexity

| VARIABLES | (1) world market share | (2) Δ world market share | (3) Δ employment | (4) Δ VA | (5) Δ GO |
|-----------------------------------|------------------------------|---------------------------------------|-------------------------------|--------------------|--------------------|
| Value added VA (t-1) | | | | 0.00 (1.507) | |
| Gross output GO (t-1) | | | | | 0.00** (1.998) |
| product complexity (t-1) | 0.42*** (3.982) | -0.21 (-0.915) | 0.07*** (7.611) | 0.11*** (5.093) | 0.11*** (7.339) |
| Δ product complexity (t-1) | -0.00 (-0.200) | 0.00 (0.317) | -0.00 (-0.125) | -0.00 (-0.261) | -0.00 (-0.492) |
| Constant | | 0.5 (0.81) | -0.21 (0.49) | 0.02 (0.52) | 0.05 (0.38) |
| Observations | 500 | 500 | 500 | 500 | 500 |
| R-squared | 0.335 | 0.061 | 0.201 | 0.216 | 0.349 |

pval in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Country product networks and capabilities

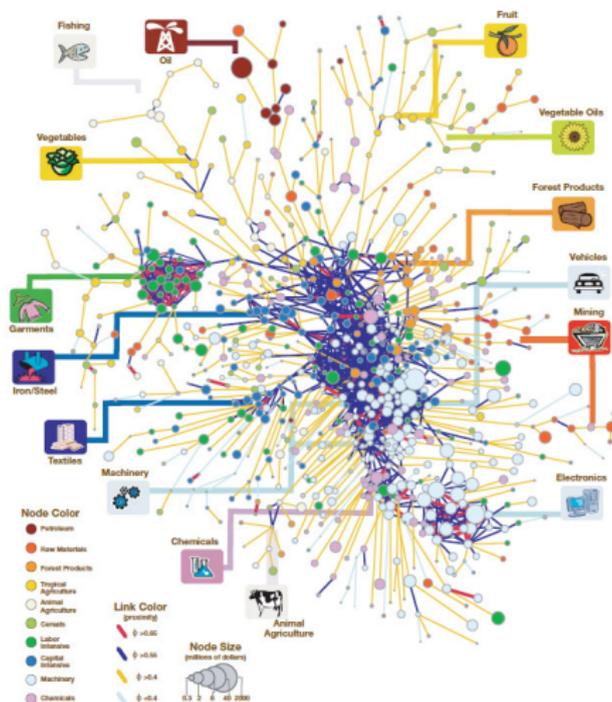


Figure : ex Barabasi et al (2007)

The product space: key measures

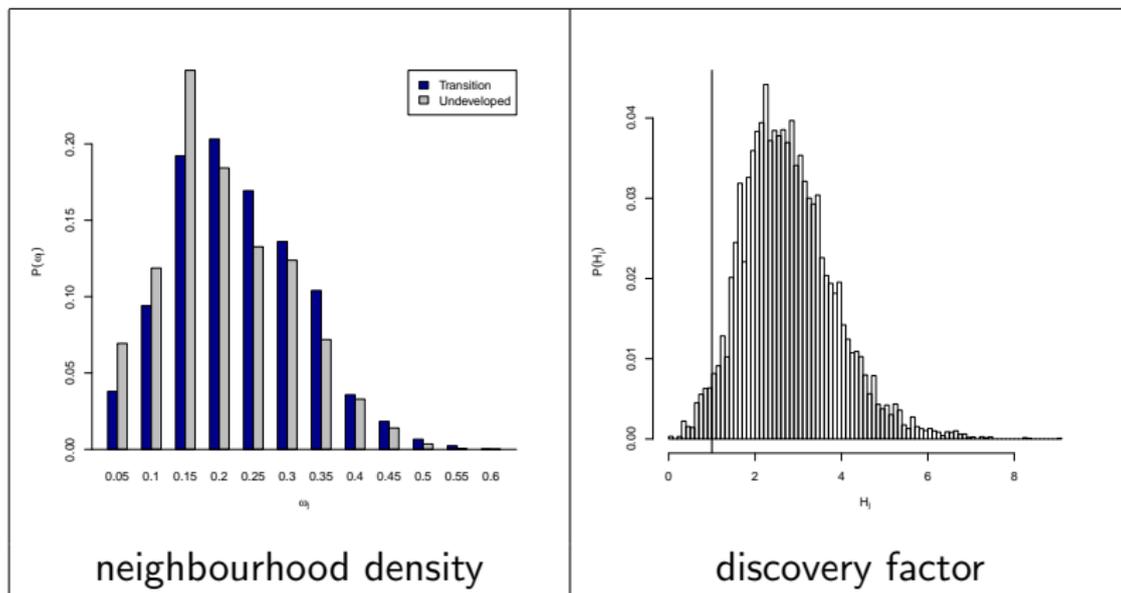
$$\phi_{p_i, p_j} = \min [P(RCA_i | RCA_j), P(RCA_j | RCA_i)]$$

- “Proximity:” links product i to any other product j in world trade (network edge)

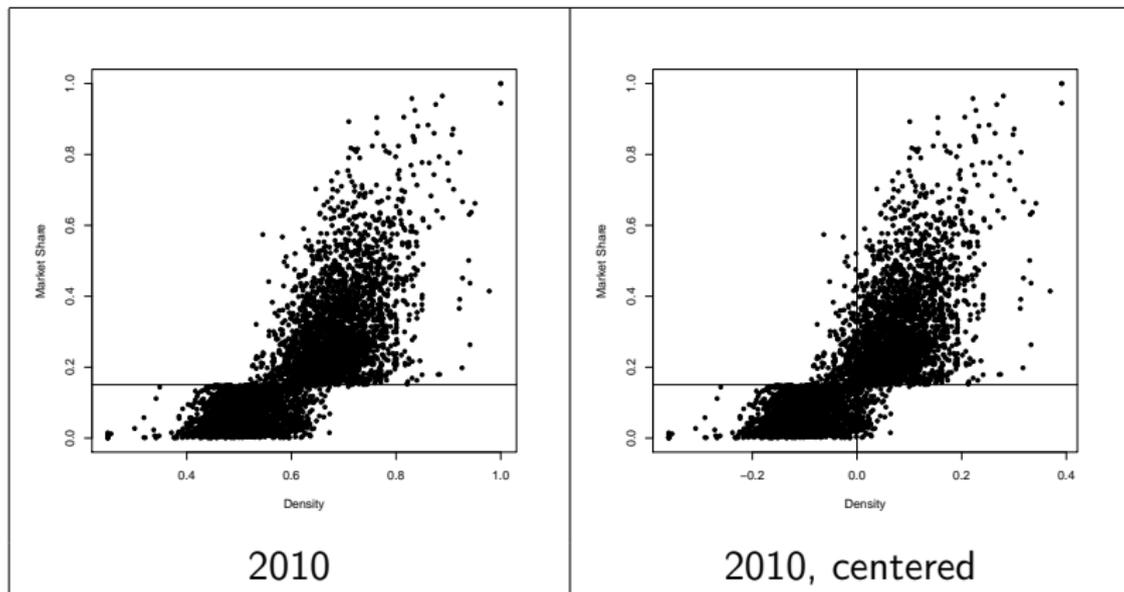
$$\omega_j^k = \sum_i x_i \phi_{p_i, p_j} / \sum_i \phi_{p_i, p_j} \quad x_i = 1 \quad \text{if } i \text{ exported with RCA}$$

- “Neighbourhood density”:
 - measures the proximity of a product j to a country's productive structures.
 - equals 1 if a country produces all products in the neighbourhood of product j in the product space.
 - Indicator for complementary capabilities: factor substitutability across products in a country.

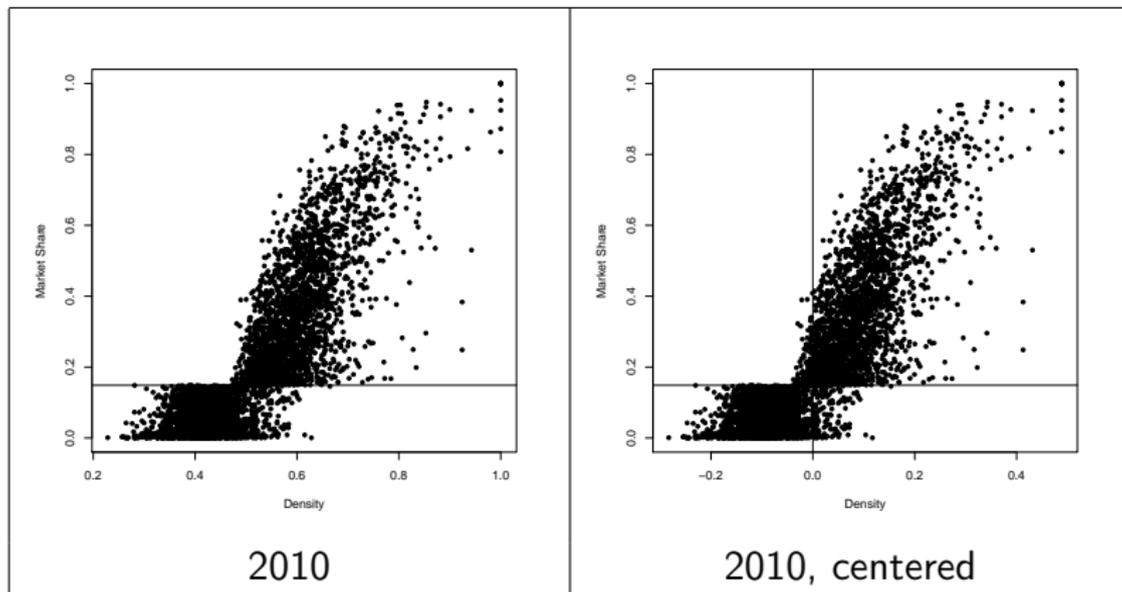
New products and the neighbourhood density



Density vs. world market share: EU 27



Density vs. world market share: China



Neighbourhood density is strongly related to comparative advantage

| VARIABLES | (1) | (2) | (3) | (4) | (5) | (6) |
|--------------------------|---------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| | RCA Dummy | RCA Dummy | RCA Dummy | RCA Dummy | RCA Dummy | RCA Dummy |
| Neighbourhood density | 0.371*** (158.0) | 0.378*** (160.0) | 0.374*** (169.8) | 0.374*** (168.5) | 0.371*** (168.9) | 0.377*** (172.5) |
| Complexity score product | 0 | 0.0562*** (29.94) | 0 | 0 | 0 | 0.0532*** (28.08) |
| Grubbel Lloyd Index | | 0 | 0.0206*** (13.11) | | 0.0322*** (21.15) | 0.0352*** (23.53) |
| Quantity margin export | | | | 0.0946*** (63.84) | 0.101*** (65.13) | 0.0939*** (62.58) |
| Unit value margin export | | | | 0.0233*** (24.49) | 0.0242*** (25.43) | 0.0235*** (25.41) |
| Constant | 0.382*** (33.19) | 0.393*** (37.92) | 0.493*** (63.70) | 0.491*** (63.85) | 0.493*** (65.72) | 0.505*** (74.82) |
| Observations | 649,721 | 649,721 | 649,317 | 636,787 | 636,787 | 636,787 |
| R-squared | 0.476 | 0.486 | 0.482 | 0.496 | 0.499 | 0.508 |

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.
Country and time dummies not reported

Neighbourhood density and economic performance at the sector level

| VARIABLES | (1) world market share | (2) Δ world market share | (3) Δ employment | (4) Δ VA | (5) Δ GO |
|--------------------------------------|------------------------------|---------------------------------------|-------------------------------|--------------------|--------------------|
| Value added VA (t-1) | | | | 0.00* (1.663) | |
| Gross output GO (t-1) | | | | | 0.00** (2.197) |
| neighbourhood density (t-1) | 14.78*** (6.893) | -1.25 (-0.260) | -0.30 (-1.413) | -0.10 (-0.197) | -0.13 (-0.392) |
| Δ neighbourhood density (t-1) | 0.34 (0.213) | -5.84 (-1.645) | 0.80*** (5.171) | 0.88** (2.467) | 0.99*** (4.245) |
| Constant | -1.88*** (0.00) | -0.68 (0.57) | 0.15*** (0.00) | 0.15 (0.22) | 0.16** (0.04) |
| Observations | 500 | 500 | 500 | 500 | 500 |
| R-squared | 0.375 | 0.065 | 0.156 | 0.183 | 0.301 |

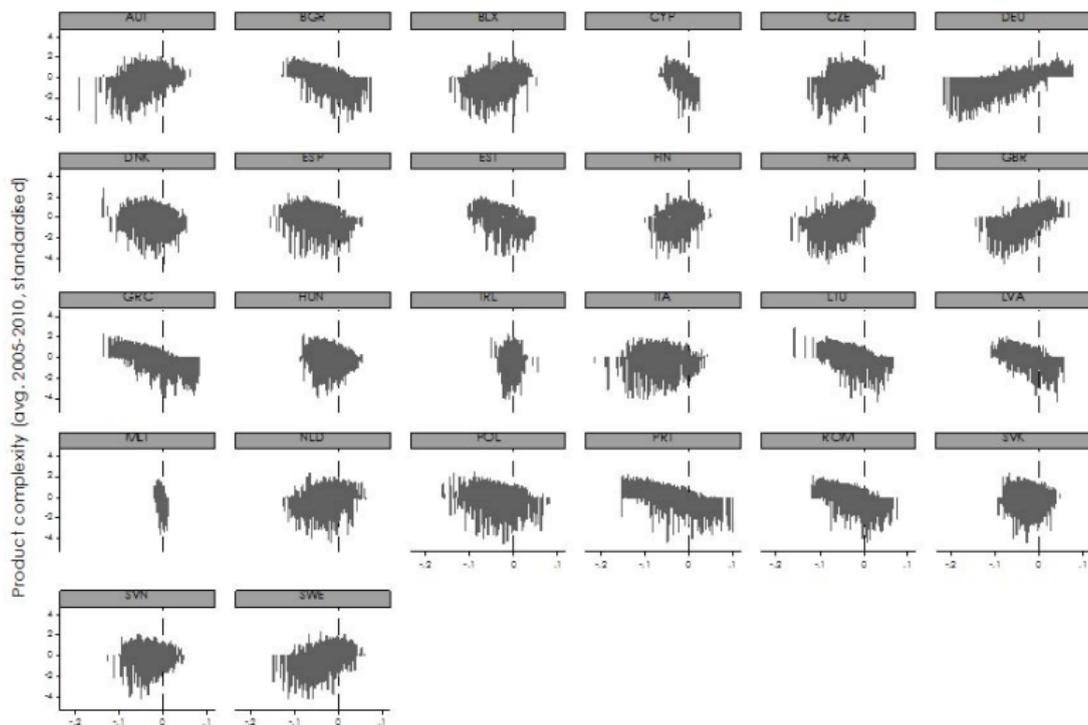
pval in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Why do productive structures develop along trajectories?

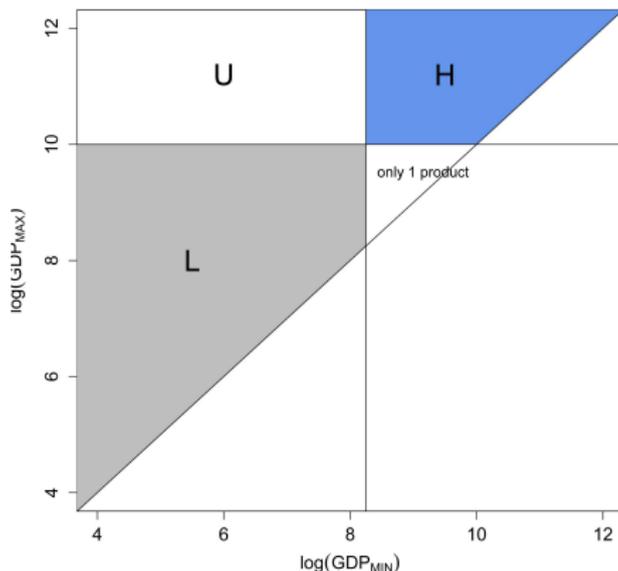
- Human learning ...
 - Knowledge accumulates (at the company level) through learning-by-doing, and knowledge is embodied in individuals and company routines (Nelson - Winter 1982, Dosi 1988 JEL)
 - product specific routines are perpetuated and further developed in ever new products (e.g. Breschi, Lissoni, Malerba, RP 2003)
- How does diversification then happen?
 - following the evolutionary theory of the firm, firm growth is a progressive process of **related** diversification (due to minimum efficient scale, changes in consumer demand, e.g. Penrose 1959)
 - new industries grow out of old industries, or are the outcome of a recombination of competencies from different sectors (e.g. Klepper and Simons 1997/2000 ICC/SMJ)
 - spin-offs have higher survival probability if the founder had prior experience in a related industry (e.g. Klepper 2007 MS)
- Hence: Relatedness and similarity in production or export patterns across

Undeveloped products across EU countries



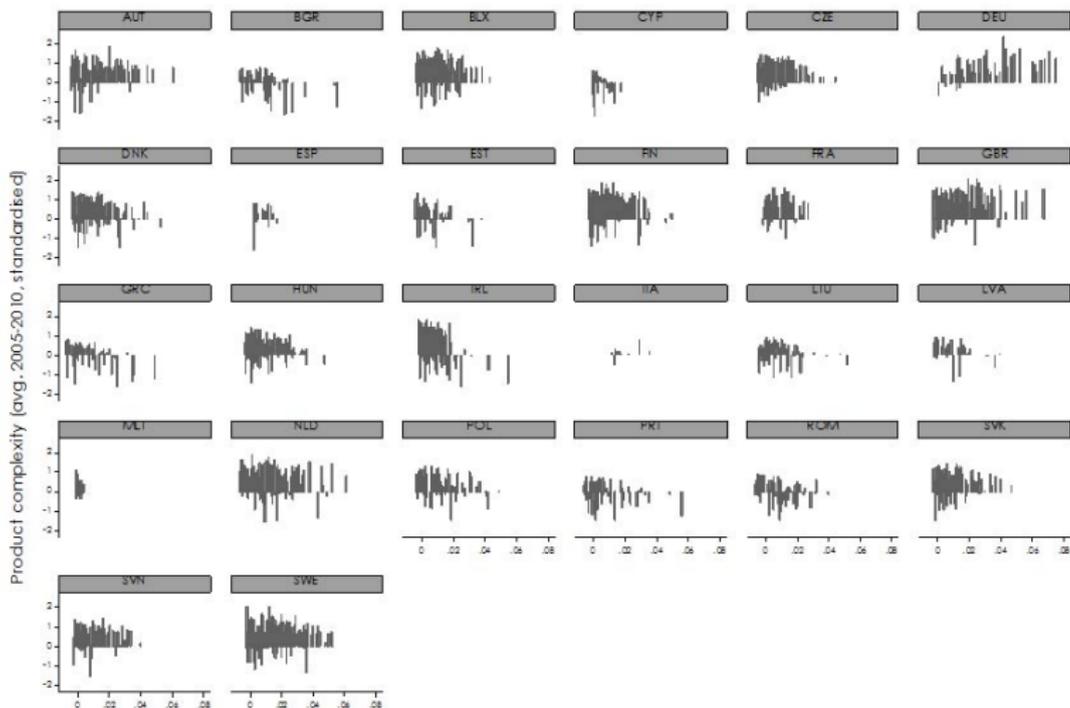
Centered density (avg. 2005-2010)

Construction of an opportunity set (Sutton - Treffler 2011)



- Definition opportunity set: $RCA < 0.5$; H-product & $PRODY_p > avg.PRODY_c$; or uninformative product and $PRODY_p > avg.PRODY_c$

Opportunity sets across EU countries



Neighbourhood density (avg. 2005-2010, centred)

Pathways for upgrading: Sector perspective

| NACE | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 15 | 0.17 | 0.17 | 0.13 | 0.14 | 0.13 | 0.14 | 0.16 | 0.15 | 0.12 | 0.13 | 0.16 | 0.15 | 0.13 | 0.14 | 0.14 | 0.09 | 0.14 | 0.09 | 0.11 | 0.16 | 0.12 | 0.11 |
| 16 | 0.15 | 0.45 | 0.13 | 0.20 | 0.16 | 0.14 | 0.15 | 0.17 | 0.13 | 0.13 | 0.17 | 0.16 | 0.14 | 0.14 | 0.13 | 0.10 | 0.15 | 0.10 | 0.11 | 0.14 | 0.12 | 0.11 |
| 17 | 0.11 | 0.13 | 0.24 | 0.20 | 0.19 | 0.16 | 0.13 | 0.06 | 0.08 | 0.16 | 0.18 | 0.18 | 0.14 | 0.19 | 0.16 | 0.13 | 0.17 | 0.15 | 0.13 | 0.14 | 0.13 | 0.17 |
| 18 | 0.23 | | 0.25 | 0.36 | 0.28 | 0.17 | 0.13 | 0.07 | 0.04 | 0.09 | 0.15 | 0.17 | 0.11 | 0.16 | 0.13 | 0.10 | 0.17 | 0.12 | 0.10 | 0.12 | 0.12 | 0.16 |
| 19 | 0.16 | | 0.18 | 0.20 | 0.25 | 0.12 | 0.11 | 0.13 | 0.07 | 0.12 | 0.16 | 0.16 | 0.12 | 0.16 | 0.14 | 0.11 | 0.17 | 0.13 | 0.11 | 0.13 | 0.13 | 0.16 |
| 20 | 0.13 | | 0.13 | 0.16 | 0.16 | 0.21 | 0.15 | 0.15 | 0.09 | 0.10 | 0.15 | 0.15 | 0.12 | 0.15 | 0.14 | 0.08 | 0.15 | 0.10 | 0.10 | 0.15 | 0.12 | 0.11 |
| 21 | 0.13 | | 0.13 | 0.12 | 0.13 | 0.24 | 0.23 | 0.18 | 0.22 | 0.14 | 0.19 | 0.18 | 0.17 | 0.18 | 0.19 | 0.11 | 0.18 | 0.12 | 0.15 | 0.20 | 0.15 | 0.13 |
| 22 | 0.16 | | 0.17 | 0.19 | 0.19 | 0.25 | 0.25 | 0.26 | 0.14 | 0.15 | 0.20 | 0.20 | 0.17 | 0.21 | 0.20 | 0.14 | 0.20 | 0.14 | 0.16 | 0.18 | 0.16 | 0.16 |
| 23 | 0.11 | | 0.10 | 0.09 | 0.09 | 0.10 | 0.12 | 0.12 | 0.23 | 0.11 | 0.13 | 0.13 | 0.13 | 0.11 | 0.12 | 0.08 | 0.12 | 0.08 | 0.10 | 0.14 | 0.11 | 0.08 |
| 24 | 0.11 | 0.18 | 0.13 | 0.09 | 0.10 | 0.10 | 0.16 | 0.15 | 0.17 | 0.18 | 0.17 | 0.16 | 0.16 | 0.17 | 0.17 | 0.14 | 0.16 | 0.14 | 0.17 | 0.16 | 0.14 | 0.13 |
| 25 | 0.12 | | 0.18 | 0.17 | 0.16 | 0.16 | 0.20 | 0.20 | 0.15 | 0.17 | 0.25 | 0.22 | 0.18 | 0.22 | 0.22 | 0.14 | 0.22 | 0.16 | 0.17 | 0.23 | 0.17 | 0.16 |
| 26 | 0.16 | | 0.15 | 0.16 | 0.15 | 0.16 | 0.18 | 0.13 | 0.15 | 0.13 | 0.21 | 0.22 | 0.17 | 0.21 | 0.20 | 0.13 | 0.21 | 0.15 | 0.16 | 0.21 | 0.16 | 0.16 |
| 27 | 0.16 | | 0.14 | 0.15 | 0.11 | 0.17 | 0.18 | 0.09 | 0.17 | 0.13 | 0.20 | 0.18 | 0.18 | 0.18 | 0.19 | 0.12 | 0.17 | 0.13 | 0.15 | 0.18 | 0.15 | 0.13 |
| 28 | | | 0.18 | | 0.16 | 0.22 | | 0.09 | 0.15 | 0.11 | 0.27 | 0.24 | 0.16 | 0.24 | 0.22 | 0.16 | 0.22 | 0.17 | 0.18 | 0.21 | 0.17 | 0.18 |
| 29 | | | 0.16 | 0.11 | 0.13 | 0.21 | | 0.08 | 0.12 | 0.11 | 0.29 | 0.23 | 0.15 | 0.22 | 0.24 | 0.14 | 0.22 | 0.16 | 0.20 | 0.22 | 0.18 | 0.17 |
| 30 | | | 0.12 | | 0.16 | 0.09 | | 0.05 | | 0.17 | 0.14 | 0.14 | | 0.19 | 0.17 | 0.25 | 0.17 | 0.24 | 0.19 | 0.12 | 0.13 | 0.17 |
| 31 | | | 0.19 | | 0.15 | 0.22 | | 0.04 | | 0.13 | 0.27 | 0.24 | | 0.22 | 0.20 | 0.11 | 0.25 | 0.20 | 0.20 | 0.22 | 0.18 | 0.18 |
| 32 | | | 0.13 | | 0.19 | 0.10 | | 0.08 | | 0.17 | 0.15 | 0.16 | | 0.22 | 0.12 | 0.19 | 0.19 | 0.30 | 0.21 | 0.12 | 0.13 | 0.19 |
| 33 | | | 0.11 | | 0.17 | 0.13 | | 0.16 | | 0.15 | 0.20 | 0.13 | | 0.20 | 0.18 | 0.17 | 0.19 | 0.21 | 0.24 | 0.24 | 0.20 | 0.17 |
| 34 | | | 0.17 | | 0.08 | 0.25 | | 0.09 | | 0.13 | 0.32 | 0.24 | | 0.16 | 0.22 | 0.09 | 0.20 | 0.15 | 0.15 | 0.30 | 0.16 | 0.14 |
| 35 | | | 0.14 | | 0.12 | 0.17 | | 0.10 | | 0.11 | 0.22 | 0.18 | | 0.18 | 0.15 | 0.10 | 0.15 | 0.15 | 0.15 | 0.19 | 0.18 | 0.14 |
| 36 | 0.11 | | 0.16 | 0.13 | 0.14 | 0.13 | 0.14 | 0.12 | 0.08 | 0.15 | 0.20 | 0.13 | 0.11 | 0.15 | 0.13 | 0.14 | 0.15 | 0.15 | 0.15 | 0.11 | 0.12 | 0.18 |

Policy implications I

- The direction of economic development goes from less to more complex products; this is not necessarily related to any specific industry or specific productive structures
- Sophistication of productive structures related to economic performance: upgrading to more complex structures related to general quality of institutions (education, STI, quality of governance)
- The development of the productive structures of an economy is highly cumulative! → Changes need to be rooted in current capabilities, long jumps are improbable!
- The degree of factor substitutability across products (neighbourhood density) key determinant of export success. Hence:
 - Factor substitution mechanisms need to operate adequately (e.g. mobility of workers, common standards...) → Single Market!
 - Minimum set of complementary capabilities needed to become significant exporter in “undeveloped” products!

Policy implications II

- Smart Specialisation seems to do the trick here, but
 - the regional focus may be too narrow: competitive strengths of one region may be related to varieties of products and capabilities not present in a region;
 - this is potentially aggravated by the goal to avoid “duplication of efforts” across regions...
- Smart Specialisation Strategies should say more about:
 - Diversification: This is a process in which areas of weakness develop into areas of strength by drawing on knowledge and factor base of current areas of strength.
 - Limited opportunity: how to deal with regions with little opportunity? How to avoid they get trapped in inferior productive structures? What are the potentials for such regions to join international value chains on the basis of their current capabilities?

Key references

- 1 Hausmann, R., Hidalgo, C. A., “The network structure of economic output”, Journal of Economic Growth, 2011, 16, pp. 309-342.
- 2 Hidalgo, C. A., Hausmann, R., “The building blocks of economic complexity”, Proceedings of the National Academy of Sciences of the United States, 2009, 106(26), pp. 10570-10575.
- 3 Hidalgo, C. A., Klinger, B., Barabasi, L., Hausmann, R., “The product space conditions the development of nations”, Science, 2007, 317, pp. 482-487.
- 4 Sutton, J., Trebler, D., “Deductions from the Export Basket: Capabilities, Wealth and Trade”, NBER Working Paper No. 16834, 2011.
- 5 Reinstaller, A., Hölzl, W., Kutsam, J., Schmid, C., “The development of productive structures of EU Member States and their international competitiveness.”, Report for the European Commission, DG Enterprise and Industry. Specific Contract No SI2-614099; Framework Contract ENTR/2009/033.
http://ec.europa.eu/enterprise/policies/industrial-competitiveness/documents/files/2013-01-21-reinstaller-study_en.pdf