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GREEN EXPORTS AND THE GLOBAL PRODUCT SPACE: PROSPECTS FOR EU INDUSTRIAL POLICY

MARK HUBERTY* AND GEORG ZACHMANN**

Highlights

- We test if and where industrial policy to promote 'green' industry development can improve competitiveness in export markets. Proponents of 'green growth' have argued that domestic promotion of 'green' energy will generate improved comparative advantage in export markets for high-technology goods such as wind turbines or solar cells. If this holds depends on if domestic market expansion can, on its own, support firm competitiveness abroad.
- We find evidence that industrial policy may work for wind turbines, but we find no evidence that it works for solar cells. Furthermore, domestic renewable energy promotion is more likely to translate into improved international competitiveness if a country already possesses skills, technologies, and industrial sectors closely related to the sector in question. By locating the wind turbine and solar cell sectors in the global product space of traded goods, we are able to show that, net of historical competitiveness and domestic market size, green industrial policy functions best when capitalising on pre-existing industrial capacities, rather than trying to create them.
- Finally, our finding that policy appears to work for wind turbines but not solar cells may reflect the greater tradeability of solar cells, which may mean that expansion of domestic demand leads to more imports rather than expanded domestic production. While this paper suggests conditions under which green industrial policy might prove effective in economic development, it makes no claims about whether this represents an efficient approach to either growth or emissions reduction. This evidence recommends caution in using economic growth and competitiveness arguments as the primary justification for investments in renewable energy.

* Visiting Fellow, Bruegel; and University of California, Berkeley. Email: mark.huberty@bruegel.org. This work was supported by the Fulbright-Schumann Fellowship and the United States Environmental Protection Agency STAR Graduate Fellowship programmes.

** Research Fellow, Bruegel. Email: georg.zachmann@bruegel.org.

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1. Introduction

The European Union and its member states have adopted aggressive targets for rates of renewable energy adoption and energy efficiency improvements by 2020. These 20/20/20 goals were justified by a trifecta of arguments for energy security, greenhouse gas emissions reduction, and economic competitiveness. Competitiveness in particular was taken to mean not only insulation from volatile fossil fuel prices, but also the protection and promotion of global comparative advantage for EU firms specialising in so-called 'green goods.' These EU-level goals were mirrored, and in many cases led by, member state policy that justified subsidies for the expansion of renewable energy markets at home as support for export-led growth abroad. As a result, the energy sector now receives the kinds of industrial policy support that the neoliberal policy consensus had made unthinkable for other sectors. Like earlier rounds of industrial policy, 'green growth' was to deliver improved productivity and new jobs in rising sectors, this time with the added bonus of ecological stability.

The return to industrial policy raises persistent questions of whether and when states can effectively sponsor the creation or competitiveness of new industrial sectors. This paper tests one aspect of this debate: whether state support for renewable energy can, on its own, grow new 'green' industrial sectors, or whether those sectors emerge from complex constellations of related industrial expertise. We find support for the argument that state support for renewable energy industries at home can develop export competitiveness abroad. But that support appears to work best when the domestic economy already has the constellation of skills, industries, and institutions that act as precursors to the creation of new 'green' industrial sectors. Subsidising the expansion of renewable energy markets at home can help support the repurposing of these skills for renewable energy goods. But it does not necessarily create these skills or capabilities anew. Thus 'green growth' faces the same set of challenges that industrial development has always faced. That the goods in question are 'green' does not solve the underlying problem of how to best structure skill and capital formation so as to provide durable comparative advantage in competitive world markets.

2. Infant industries and incomplete information: industrial policy and its discontents

The 'green growth' debate is not new. Rather, it merely extends an ongoing argument over whether state sponsorship of certain sectors or industries can actually stimulate economic growth. Advocates of state action have claimed that a range of economic externalities interfere with the establishment of new industries, and justify state support in the name of economic development. Taken together, these externalities justify so-called 'Hamilton-List' interventions that support industries through the initial period of development. But those opposed to any kind of state support can point to numerous examples of state intervention that cost too much, gained too little, or distorted economic development into obsolete or inefficient sectors.

Advocates of targeted intervention into new sectors typically couch their arguments in terms of supporting high-growth 'infant industries.' This Hamilton-List infant industry argument assumes that due to externalities or imperfect capital markets a pure market solution (i.e., no government intervention) would keep the infant industry underdeveloped compared to its socially optimal size.

Three primary externalities are commonly cited. First, the learning-by-doing hypothesis provides a strong argument—one found often in the green growth literature—for why markets alone may fail to provide for the socially optimal development of new industries. New firms in new industries generate substantial knowledge simply by participating in the sector—so-called 'learning by doing.' Following Lucas (1993), learning is the by-product of applying labour and capital to new production processes. Hausmann and Rodrik (2003) highlight the importance of entrepreneurs exploring in which sectors an entire country might be competitive on the international market. But this kind of activity generates spillover benefits that the first-entrant firms can't internalise. These externalities include the education of the (mobile) labour force, difficult to protect process innovation, or simply demonstration effect knowledge—proof that something can in fact be done. The inability to internalise these benefits leads to under-development of industry for a variety of reasons: firms are reluctant to generate benefits for competitors; capital markets may be reluctant to invest in untested ideas; and labour may be reluctant to invest in new skills for industries whose viability remains unverified. These effects can lead to under-development of new sectors compared to socially optimal levels.

Cluster externalities create a second justification for state intervention in infant industries. In brief, first entrants to a new sector might provide the seeds for widespread productivity improvements from which they only partially benefit. As Rodriguez-Clare (2007) shows, these clustered externalities take two forms. Marshallian specialisation externalities can create complementary patterns of firm specialisation that increase productivity across the value chain.[1] Jacobian externalities arise from the productivity-improving benefits of competition between firms in the same sector. Marshallian specialisation can help create a competitive value chain, while Jacobian specialisation can improve the productivity of each link in that chain (van der Panne and van Beers, 2006).[2] Thus, the initial investors in an infant industry might be providing the nodes for a new cluster. If the company cannot entirely internalise the corresponding benefits, the individual level of investment will be suboptimal.

Finally, pure economies of scale may create a third externality that leads to under-investment by potential new market entrants. For industries with severe scale efficiencies, only one or a few companies might enjoy a natural monopoly rent in the global market.[3] A strategic game for entry in this market would arise. Governments could be interested in engaging in such strategic rivalries to help their domestic companies as the domestic social benefit of attracting such an industry might exceed the private benefits of the corresponding investor (Brander and Spencer, 1985).

Each of these externalities would argue for welfare-enhancing state intervention. If private markets under-invest because of the inability to fully benefit from the learning, clustering, or social externalities that those investments would create, government subsidy could correct this market failure. Done appropriately, state interventions at the sectoral level could theoretically be welfare enhancing from a national perspective.

What counts as 'appropriate' drives to the heart of the debate over industrial policy. Various government policies to support infant industries have been proposed: creating domestic demand through obligations or public procurement; subsidising R&D, investments or even production; provision of targeted public goods (education, infrastructure); export subsidies; and import restrictions. All these policies incur economic cost.[4] And they all require picking a sector to support, choosing the duration of support, and deciding on the volume of support. Economic literature indicates that for political-economy reasons governments often support the wrong sectors, too long and with too much money.[5]

Consequently the classic trade-off between government failure and market failure arises. On the one hand, the 'Mill Test' asks whether the protection or subsidy can eventually lead to a sector capable of surviving

1 Rodriguez-Clare (2007): 'Clusters arise in the presence of Marshallian externalities, which signifies that firms benefit from the production and innovation activities of neighboring firms in the same and related industries'. But 'Marshallian externalities are not an intrinsic characteristic of an industry: the same industry could generate Marshallian externalities in one place and not the other, in one stage of its evolution and not another.'

2 'In a recent review of the evidence, Rosenthal and Strange (2004) conclude that an important component of ME is knowledge spillovers, which are obviously stronger for knowledge intensive industries.' (quoted from Rodriguez-Clare, 2007).

3 The classic example is aviation, where two firms—Boeing in the United States and Airbus in the European Union—comprise the bulk of the commercial jet aviation market. Both firms and governments have recently suffered setbacks at the World Trade Organization for unlawful state aid, albeit of different forms.

4 For instance, Frankel and Romer (1999) show that protecting domestic industry from foreign competition can deprive domestic economies of the gains from trade.

5 On the impossibility to pick winners Baldwin and Robert-Nicoud (2007) argue that the asymmetric appropriability of rents implies that losers lobby harder and are thus more likely to receive subsidies than winners, the opposite of the preferred outcome. Earlier explanations include the protection for sale argument by Grossmann and Helpman (1994) and the 'social insurance' explanation of Hillman (1989).

international competition without aid. On the other, the 'Bastable Test' argues that the aid is only justifiable if the discounted future benefits from the supported sector exceed the present cost of support (Corden, 1997). Some general findings of the literature evaluating development strategies suggest that 'export led growth' strategies that target interventions to potentially exporting industries have worked better than 'import substitution' strategies.[6] There is, however, no consensus whether infant industry protection was the primary causal factor in successful cases of export-led growth.[7]

Much of the success of state support appears contingent on different national economic and policy contexts. But the literature on the effectiveness of infant industry interventions has rarely given formal consideration to such initial conditions. This is understandable, as initial conditions encompass a universe of potential variables that make each case look idiosyncratic.

Recently, the 'product space' literature has provided a way of abstracting this multidimensional problem in a constructive way. Hausmann and Klinger (2006) and Hidalgo et al. (2007) proposed to visualise how several sectors cluster together with respect to their coinciding export competitiveness. Hausmann and Klinger (2006) suggested that a country's location within the global product space can indicate how easily they may move into new sectors. Countries competitive in one sector may find moving into export markets in closely related sectors easier than in distant sectors. For instance, moving from one kind of textile product to another may be much easier than from textiles to industrial chemicals. The reasons for this could be manifold and difficult to disentangle. But, the presence of 'close' sectors can be supposed to be a good proxy for the existence of favorable initial conditions for the development of a corresponding sector (see section 4).

3. The 'green goods' sector as an exceptional infant industry

Environmental goods—so called 'green industries'—are equally subject to this set of arguments for and against state support of markets. These industries comprise technologically sophisticated traded goods like wind turbines or solar cells, are subject to intense international competition, and display many of the externalities—most notably learning-by-doing[8]—that feature in standard arguments for state support.

But in addition to these features, 'green goods' also occupy sectors prone to severe environmental or security externalities. This is particularly true for climate change mitigation goods like renewable energy, which are not presently cost-competitive with fossil fuels unless these externalities are somehow priced in. Thus there are good reasons to believe that 'green goods' are even more susceptible to under-investment compared to the social optimum than environmentally undifferentiated infant industries. As Unruh (2000, 2002) and Acemoglu et al. (2009) have argued, these externalities may lock out climate change mitigation goods unless overcome via concerted state action.

Apart from the environmental problems this lock-out poses, states have recently become concerned that lock-out will also deprive them of comparative advantage in new 'green' industries. So-called 'green growth' has taken its cue from successful exporters of green goods, like Denmark or Germany.[9] The German Ministry

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6 According to de Melo and Robinson (1992), '[Westphal (1978); Westphal, Kim, and Dahlman (1985)] believe that infant-industry protection, export promotion, and intervention was at the heart of ELG.' Other proponents of this view are Hausmann, Hwang, and Rodrik (2006).

7 According to de Melo and Robinson (1992), [Balassa and Associates (1982), Balassa (1985), Bhagwati (1988), Krueger (1985), Little (1982) and Noland and Pack, (2003)] claim that a relatively neutral set of incentives across activities, which promotes allocative efficiency, accounts for the superior performance of ELG.

8 See the large literature on 'learning/experience curves' for renewables (eg Jamasb, 2007).

9 The popular and policy arguments on green growth span a wide range of economic, environmental, and social concerns. A sampling of four categories demonstrates this diversity:

1. **Keynesian demand stimulus** for short-term job creation via deficit-financed investment in energy efficiency and energy infrastructure
2. **Improved trade competivieness** via reduced exposure to terms-of-trade pressures from fossil fuel imports, particularly petroleum and natural gas

for the Economy attributes 280,000 new jobs and €31 billion in turnover to the renewable energy sector as of 2008.[10] The Danish Wind Industry Association cites the wind sector as responsible for 8.5% of all Danish exports, 24,000 jobs, and €7 billion in turnover.[11] These tangible economic benefits may come alongside reduced dependence on energy imports and reduced domestic pollution. They have also helped sustain enthusiasm for green energy and emissions reduction.[12] These cases have enabled governments to rationalise state investment in 'green' industries on job creation and competitiveness, as well as environmental grounds.

The European Union was an early leader in appealing to economic growth and competitiveness to rationalise state support for 'green' renewable energy industries and markets. The European Commission, in its 1997 energy white paper, appealed to the export advantages that Europe could capture via early sponsorship of renewable energy.[13] This was followed shortly by a 1998 report from the European Parliament, which asserted the potential for 'exporting technology and services for the use of renewable energy' and stressed 'the competitive advantages currently enjoyed by European producers thanks to high technology and hence a more favourable export position in competition with the USA and Japan', but bemoaned the 'a definite lack of effective aid, in particular for small and medium-sized enterprises'. To remedy this gap, the Parliament '[called] on the Commission to draw up a study of the foreign trade implications for the EU of support for renewable energies'.[14]

This early appeal to export competitiveness was later echoed in the European Union energy directives and their binding targets for renewable energy use in the EU. The 2001 renewable energy directive (2001/77/EC) explicitly stressed 'export prospects' in justifying the 12% renewable electricity penetration target for the EU15 countries by 2010. That target was followed by the 20% target for the EU-27 established in the 2009 Climate and Energy Package and echoed in the Europe 2020 manifesto.[15] The 2009 documents established three justifications for renewable energy: greater security of supply, reduced greenhouse gas emissions, and improved national competitiveness in 'green' energy technologies.[16] Competitiveness has arguably become even more important since these directives passed, given the renewed competition from the United States and China. Commissioner for Energy Günther Öttinger argued for increased European spending on decarbonisation technologies by stating that 'in global competition we need to avoid that we start lagging behind China and the USA.'[17]

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3. **Increased innovation in response to greater administrative constraint**, otherwise known as the 'Porter Hypothesis'
4. **Revealed comparative advantage** through promotion of export sectors in high-value renewable energy markets

Note that these justifications exist apart from whether, as the Stern Report (2007) argued, investment in emissions reduction today is justified on the basis of potentially very high costs from unmitigated climate change in the future. Avoided costs are not the same as tangible benefits, either for current living standards or for the political economy of policy sustainability.

10 'Im Jahr 2008 erzielte der Sektor einen Inlandsumsatz von rund 31 Milliarden Euro und zählte rund 280.000 Brutto-Beschäftigte.' (BMWi 2010).

11 Danish Wind Industry Association, 'Annual Statistics 2010' at www.windpower.org/en/knowledge/statistics.html

12 Eg, for Germany, the 2010 report on the economy reiterates the idea that environmental protection and economic growth can go hand in hand: 'Gerade für Deutschland als Vorreiter bei den erneuerbaren Energien und Energieeffizienz gehen Wohlstandsmehrung und Umweltschutz Hand in Hand, wenn das klimapolitisch Notwendige so ausgestaltet wird, dass es auch energiepolitisch sinnvoll ist sowie Wachstum und Beschäftigung Rechnung trägt.' (BMWi 2010).

13 European Commission (1997).

14 On 15 May 1998 the Parliament authorized the Committee on External Economic Relations to draw up a report on the new prospects of the European Union in exporting technology and services for the use of renewable energy.

15 European Commission (2010).

16 'Meeting our energy goals could result in € 60 billion less in oil and gas imports by 2020. This is not only financial savings; this is essential for our energy security. [...] Meeting the EU's objective of 20% of renewable sources of energy alone has the potential to create more than 600 000 jobs in the EU. Adding the 20% target on energy efficiency, it is well over 1 million new jobs that are at stake.' (The European Commission, 2010)

17 Speech of Commissioner Oettinger at ENERI 2010, Belgian Presidency Conference on Infrastructure of Energy research. Brussels, 29 November 2010.

4. Testing the green growth hypothesis

Under what circumstances might these justifications for infant industry support to 'green' industries hold? Can competitiveness and economic growth really justify subsidy of 'green' goods on their own, in addition to the environmental goods they provide? To analyze whether industrial policy motives for renewable electricity generation technologies could be considered as a valid motive for renewable energy support schemes, we proceed with two different analyses. First, we show that 'green' products do not comprise any unique category, but are instead different products that reside in different parts of the product space. This motivates looking into the different technologies separately. We then investigate three aspects of the effectiveness of state aid:

1. Does state aid to green energy correlate with the size or scope of domestic markets for 'green' energy goods?
2. Does the size of domestic markets for green or renewable energy—themselves opportunities for 'learning by doing'— correlate with international competitiveness in markets for renewable energy goods?
3. Does competitiveness in green energy goods grow out of earlier patterns of competitiveness in related sectors?

(1) and (2) reflect the link, implied by policymakers in the EU and elsewhere, between government support for domestic market growth and international competitiveness. (3), in contrast, tests an alternate hypothesis: that the ability to grow into competitive positions in global markets for 'green' goods is in fact contingent on pre-existing structures of the domestic economy, rather than simply just the size of one's domestic 'green' goods market. If true, that would suggest that using policy to create new 'green' sectors in the absence of favourable initial conditions might prove difficult and expensive.[18]

To establish whether and how export competitiveness in renewable energy industries relates to broader economic factors, we need two measures: one, of global competitiveness, and two, of the economic factors themselves. Revealed Comparative Advantage (*RCA*) provides a standard and straightforward way to measure the relative competitiveness of economies on world export markets.[19] To move from broad observations on trade patterns to cleanly specified arguments about policy intervention and economic change, we follow Hidalgo et al. (2007) in defining a global product space that captures relationships between trade patterns for different products. The product space allows us to formalise and quantify networks of related products and track the evolution of those networks over time. Furthermore, consistent with Hidalgo and Hausmann (2009), we can view the product space as representation of the underlying economic factors that influence competitiveness. Since green products like solar cells and wind turbines come into global markets later than hypothesised supporting sectors, we can watch the emergence of global trade in these products and its relationship to pre-existing patterns of industrial competitiveness that reveal information about the economic capabilities of individual countries.

Subject to the limitations of the state aid data, we find limited support for the relationship between state aid and market size. But market size and competitiveness are highly correlated, particularly for wind turbines. In contrast, global competitiveness in solar cells appears to depend more heavily on pre-existing structures of economic competitiveness.

[18] Consequently, we are able to check different pieces of the argumentation chain that indicates that (i) support schemes drive renewables deployment, (ii) deployment encourages a domestic supply of the technology, (iii) via learning-by-doing and other externalities, the domestic technology supply improves its global competitiveness and (iv) the state support schemes eventually lead to a prospering renewable technology sector that increases the net welfare.

[19] For a survey and references on other measures see http://www.mpsge.org/qtool/competitiveness.pdf

4.1. Defining the global product space

Consistent with Hidalgo et al. (2007), we define the product space as the matrix *P*, containing the proximities $prox_{i,j}$ between goods *i* and *j*. The proximity is the conditional probability that a country that exports good *i* also exports good *j*. We define exporting to mean a revealed comparative advantage RCA_i of greater than 1.

Formally, we define the revealed comparative advantage for country *c* in good *i* as

$$RCA_{c,i} = \frac{\dfrac{x_{c,i}}{\sum_i x_{c,i}}}{\dfrac{\sum_c x_{c,i}}{\sum_{c,i} x_{c,i}}} \tag{1}$$

Thereby, $x_{c,i}$ is the export of good *i* by country *c*. Consequently, the RCA measures, whether a country exports more of good *i* relative to its total exports, than the share of good *i* in global exports. Given the *RCA* values for countries *c* and goods *i*, we compute the proximity matrix as

$$p(x_j \mid x_i) = \frac{\sum_c RCA_{c,j} > 1 \mid RCA_{c,i} > 1}{\sum_c RCA_{c,i} > 1} \tag{2}$$

$$prox_{i,j} = \min(p(x_j \mid x_i), p(x_i \mid x_j)) \tag{3}$$

Equation 3 generates a symmetric proximity matrix of dimension $n \times n$, for *n* globally traded goods. The proximity is the conditional probability of being competitive in good *j* given that a country is competitive in good *i*. Consistent with Hidalgo et al. (2007), we take the minimum of $p(x_j \mid x_i)$ and $p(x_i \mid x_j)$ to ensure that countries which are sole global exporters for some good do not dominate the calculation of proximity values.

The product space provides a latent representation of the relationships between competitiveness in different sectors. How exactly those relationships should be characterised remains the subject of some dispute. Earlier analysis of industrial policy in the *filiere* tradition emphasised the importance of strategic sectors—as opposed to skills or capital or other abstract factors—for comparative advantage.[20] In that tradition, the product space was sometimes taken literally: if sector A was proximate to sectors B, C, and D, then a country wishing to be competitive in sector A should be in the other sectors as well.

Empirical tests of this interpretation proved uncertain. We prefer a more general interpretation of the product space: that in addition to strategic sectors that might play a role for certain products (eg, the value chain in the petrochemical industry) also represents a network of products that require similar kinds of expertise, factor inputs, firm networks, infrastructure, and institutions.[21] The later interpretation suggests different priorities for economic development. Instead of an emphasis on individual sectors, it implies an emphasis on developing the ability of the economy to move into modes of production other than those it currently occupies.

[20] For an overview of the *filiere* tradition, see Kaplinsky and Morris (2001).

[21] Hidalgo and Hausmann (2009) call this a set of 'capabilities', the diversity of which—as measured by the density of a country's competitiveness around some of set of goods—can represent a set of capabilities that can be redeployed in service of other goods.

This reading is broadly consistent with two more recent strains of political economy literature. The Varieties of Capitalism analysis argues that the categories of production countries specialise in are linked, not to specific historical expertise in one or several sectors, but to the institutional relations among labour, capital, and government; and the kinds of skill and capital formation those relations encourage (Hall and Soskice, 2001). Likewise, the analysis of the small states of northwestern Europe—Denmark in particular—emphasises the institutional ability to reallocate labour and capital among closely related but highly exposed sectors on the basis of factor formation, not prior specialisation (Katzenstein 1985).

4.2. Data

We use the six-digit product data (HS-6) from the United Nations COMTRADE database, for years 1990-2009.[22] At the six-digit level, it becomes possible to identify a range of products that can be classified as 'green'. Based on their ability to help reducing carbon emissions we define green products in the following categories: solar cells; wind turbines; nuclear power plants and parts thereof; and electric meters.[23]

The use of 6-digit data does not permit restriction of the goods that classify the product space as all 6-digit products are needed to span the entire product space.[24] Hierarchical clustering of the proximity matrix does not reveal a set of unrelated goods that can be excluded from the resulting product space.

For the purposes of constructing the green product space, we calculate the proximity matrices for years 2005-2009 and average the results across the set of products common to all years. This provides some means to mute short-term fluctuations in trade patterns.[25]

4.3. Properties of the product space

The product space was constructed by averaging the proximity matrices for the years 2005-2009. Figure 1 shows the Minimum Spanning Tree of the global product space as defined by $p > 0.5$, as calculated by Kruskal's algorithm.[26] The Minimum Spanning Tree (MST) provides a visual representation of the product space matrix. If we define each product as a node in a tree, and the distances (i.e., inverse proximities) between products as the length of the branches, then the MST chooses a tree connecting all the nodes such that the sum of the length of the branches is minimised. Thus the MST for the product space illustrates the products space using the highest-proximity connections between products. The result is a representation that privileges close connections between products as measured by their conditional probability of export, and helps represent how products cluster with their neighbors in the product space.

[22] Hidalgo et al. (2007) use 4-digit trade data to construct their product matrix. However, the 4-digit data do not allow us to identify green products in the global trade space.

[23] The HS-6 codes are, respectively, 854140; 850231; 840140; 840110; 902830; and 902890.

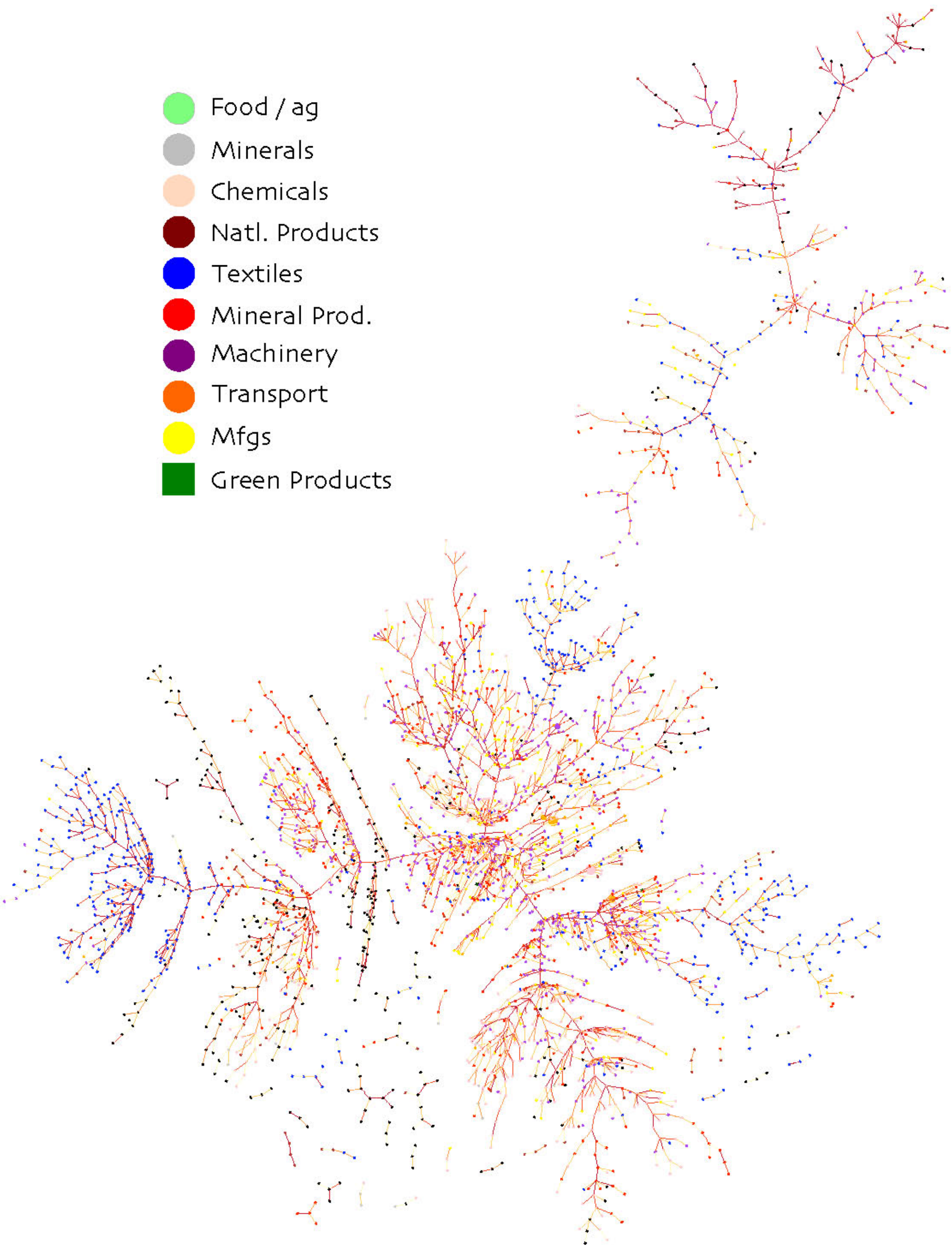
[24] At the 4-digit SITC product classification Hidalgo et al. (2007) find that only 775 of the 1006 goods represent the entire product space.

[25] Even without this averaging, the product space remains very stable over time. Spearman rank tests of the correlation between the proximity vectors for green goods over time return positive correlations with p-values of zero, indicating that patterns of proximity are relatively constant. Likewise, tests on a random sample of 50 products from the proximity matrix return the same result. These highly significant correlations between ranks over time suggest stability to the overall structure of the product space. For each year in the period 2005-2009, despite both changing trade patterns and a changing set of reporting countries, the character of the proximity between green goods and their conventional counterparts remains quite similar (see Figure 11 in the Appendix). This provides some confidence that the observations that follow are not based on the idiosyncratic choice of dates.

[26] Kruskal's algorithm provides one of several means for efficient computation of minimum spanning trees. See Kershenbaum and van Slyke (1972) for a comparison of different methods.

Darker links indicate closer proximities between nodes. Clustering of major product categories is clearly visible, particularly for textiles. Consistent with earlier work, the MST shows significant distance between clusters of expertise in industries like textiles and food production on the one hand; and high-value-add manufacturing, transport, and chemicals on the other. As Hidalgo et al. (2007) argued, this suggests the difficulty of moving an economy's comparative advantage from one sector or cluster of sectors to another. The product space provides an abstract representation of the set of characteristics—capital and skill formation, infrastructure, production networks, and retained expertise—that shape what that country can competitively produce and export. The separation of textiles and machine tools in the product space is a projection of their significant separation in a multidimensional space comprised of a range of political and economic variables that determine national comparative advantage. In the next section we are zooming into the positioning of green products in the product space.

Figure 1: Minimum Spanning Tree for the product space defined by the HS-6 data in years 2005-2009. The MST was constructed using Kruskal's algorithm. Only links with $p > 0.5$ are shown. Darker links indicate greater proximity.



5. Results

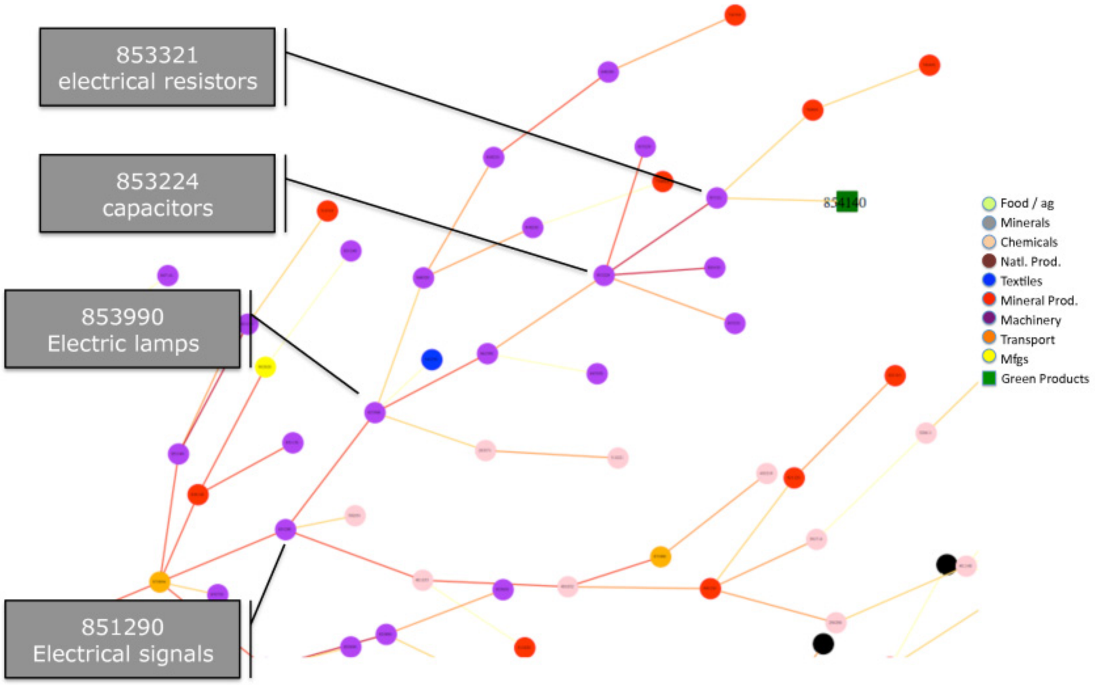
In this section we show that the analysed data are not inconsistent with the view that: (5.1) green technologies are not a product class of its own and different technologies must thus be analysed separately, (5.2) deployment of renewable electricity generation was linked to state support, (5.3) competitiveness in some renewable generation technologies is linked to the domestic market size, (5.4) Historic competitiveness in the corresponding and adjacent sectors co-determines current competitiveness.

5.1. Green products in the product space

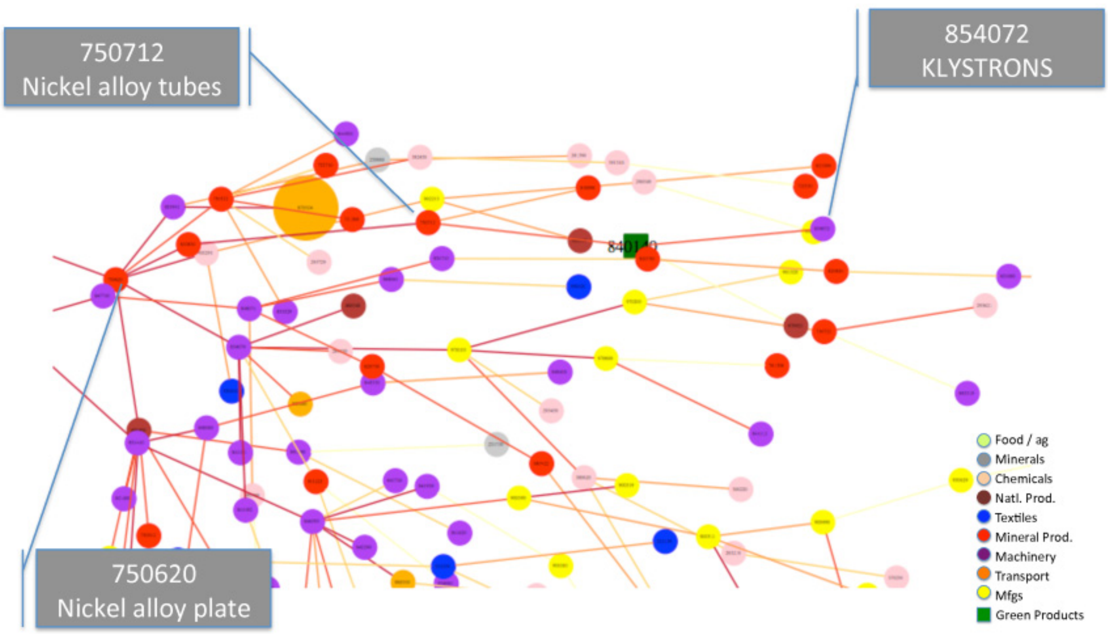
We first zoom into the MST around green products. Figure 2 shows the detailed product space surrounding solar photovoltaic cells and nuclear plant parts. The annotations indicate the products represented by nodes proximate to the green products themselves. The results are not surprising: solar cells are proximate to other sophisticated microelectronics and integrated circuit parts; nuclear power plant components are proximate to sophisticated metallurgical technologies and scientific apparatus.

We are interested in how the local properties of the product space for green goods compare to those of the product space as a whole. Figure 3 suggests that green goods are very different in their levels of integration in the product space. If we define density around a given good as the sum of other goods within some proximity threshold value, then the density of green goods at different threshold values varies widely. Nuclear reactors are poorly integrated, suggesting they require a range of specialised capabilities weakly linked to broader patterns of industrial production. In contrast, electric meters are very highly integrated into the product space, and exist in dense local networks. The other goods are distributed around the mean, with wind turbines significantly less well-integrated than the mean, and solar cells in general better-integrated. However, all goods lie within the middle 95% quantile of the data, even if their distribution around the mean is significantly different from the entire population.

Figure 2: The local product space for solar cells and nuclear power plant parts.

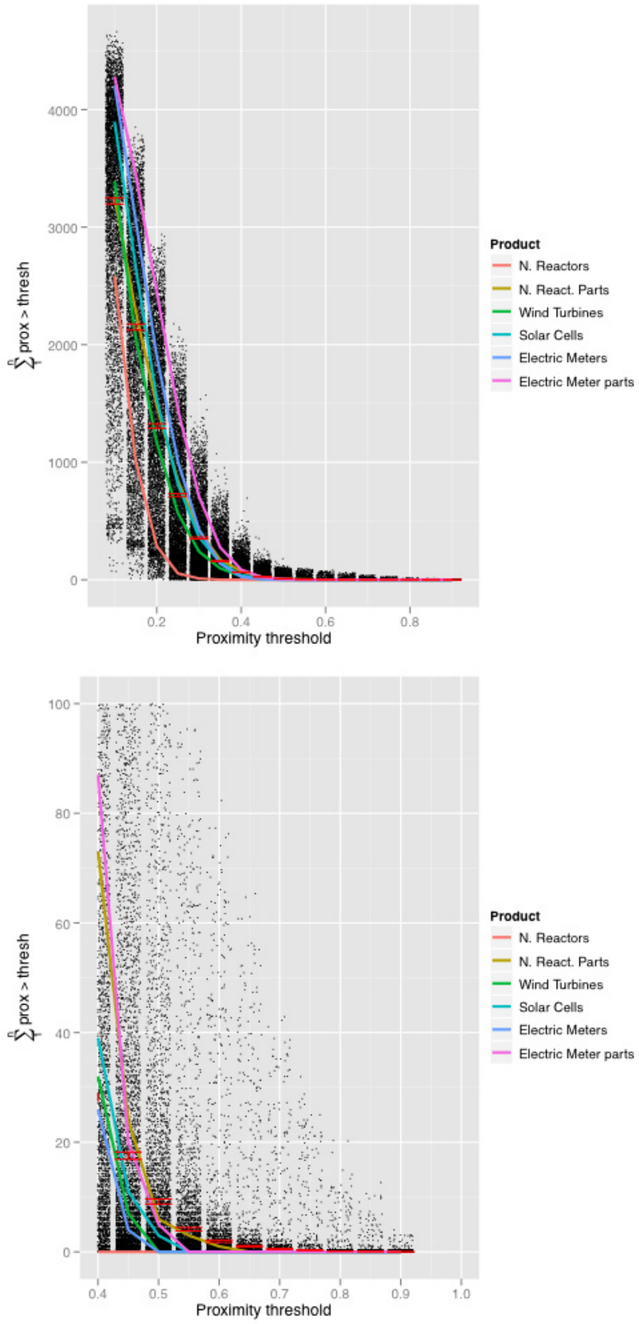


(a) The local solar cell product space



(b) The local nuclear power plant parts product space

Figure 3: Density of proximity values in the product space. Points represent the count, for each product, of adjacent goods within some proximity threshold. Green products are shown in colored lines. Error bars show the 95% confidence intervals around the mean for each threshold.

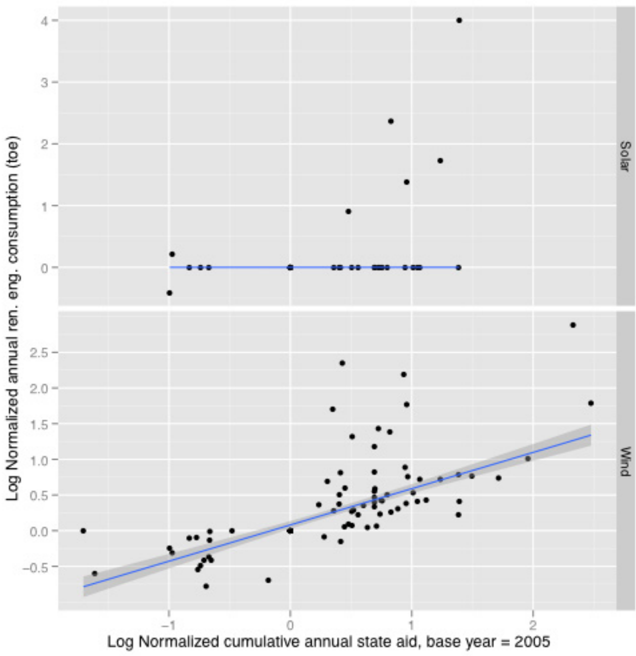


Thus the product space itself suggests that green products are not much different from their non-green counterparts. They show similar proximity to other products in their same product classification; the distribution of proximity values between green products and the rest of the product space is about that of the product space as a whole, with some products being disproportionately more isolated; and the products most proximate to green products in the Maximum Spanning Tree representation display clear sectoral relationships. Consequently, we cannot treat the six 'green products' as a group but have to analyze them individually. In the course of the subsequent analysis we will focus on the two technologies for generating electricity from renewable sources (RES-E): wind turbines and solar cells.

5.2. Hypothesis 1: State support and the market for renewable energy

To achieve the national renewable energy targets set forth in the 2009 Climate and Energy Package, each EU member state has developed a different policy mix. Policy tools include, but are not limited to, 'green certificates', 'feed-in tariffs', obligations, direct subsidies, preferential grid access regulations and tax breaks. Due to the use of different fiscal, parafiscal and non-fiscal instruments the actual size of the state support for RES-E is very difficult to assess. A measure of total state aid for environmental protection collected by the EU Directorate-General for Competition – a very imperfect indicator for RES-E support – hints to large divergences inside the EU. In 2009, total state aid for environmental protection amounted to 1.1 % of EU-27 GDP. But Germany spent over twice that—2.4%—while Italy spent only 0.12%.[27] Consequently, the national systems for RES-E support in Europe seem to differ, both in structure and in size.

Figure 4: Correlation between state aid and total consumption of renewable energy. State aid reported for 2004-2009 by the Directorate-General for Competition and is normalised within countries to 2005. Annual consumption is reported in tonnes of oil equivalent for solar and wind energy by the Eurostat and is similarly normalised by country.



If the relative scale of state support had an impact on the speed of deployment, we should observe that in recent data on market size. Figure 4 shows the correlation between cumulative environmental state aid and domestic production of renewable electricity from solar or wind. Cumulative state aid—even in so imperfect a measure as in the DG Competition data—correlates with greater domestic production of renewable energy. But this is true only for wind energy, not for solar. Two explanations may hold here. First, the imperfect measures of state aid used here may not correctly capture all forms of aid that go to solar versus to wind.

[27] In comparison to electricity consumption, the distribution is equally wide. While the member states of the EU27 spend a total of 13 bn Euro on environmental aid and consume about 3000 TWh. For Germany this ratio is 2.5 times higher and for Italy 16 times lower.

Second, wind energy is presently cheaper than solar in most European countries.[28] Thus state aid for generic renewable energy may favour adoption of wind over solar purely on the basis of market price.

The unexpectedly low correlation between environmental state aid and deployment—particularly for solar photovoltaics—may be explained by the fact that environmental state aid is no perfect proxy for the actual state support to renewables. When including non-fiscal support (eg grid connection obligations) and excluding non-renewables expenditures (eg ecosystem restoration) the interaction would probably be stronger. As the deployment of solar panels in Germany and the low share of wind in total generation in the UK suggest, the deployment is mainly driven by support and not the availability of sites. Furthermore, given the that wind and solar energy nearly always cost more than fossil fuel alternatives, market size may be a good proxy for the harder-to-measure question of state support.

5.3. Hypothesis 2: Market size and global competitiveness

The Listian or infant industry argument suggests that countries should support domestic markets as a precursor to developing internationally competitive firms to supply those markets. Section 5.2 showed that, for wind energy in particular, market size does reflect state aid to renewable energy sectors. If learning-by-doing constitutes a substantial asset in the development of firm competitiveness, then state subsidies for market expansion in the initial learning period could overcome barriers to the establishment of internationally competitive firms.

Here, we test whether that argument holds in the case of wind or solar energy production systems. If the argument holds, we might expect that countries with larger domestic markets for wind or solar energy would display greater competitiveness in world markets for wind turbines or solar cells. Two measures of capacity are used: either the raw market size, measured in billions of kilowatt hours generated per year; or the relative market size, as a percentage of overall electricity production. The absolute market size may provide a better measure of pure demand for renewable energy-related capital. To the extent that we believe that competitiveness contains a significant learning-by-doing component, which domestic market expansion supports, then absolutely larger domestic markets may matter more. However, it may also be that the relative contribution—in percentage terms—better reflects the commitment of any given nation to domestic market development. Absent a better theory of exactly how market size relates to competitiveness, we show both outcomes.

Once again, the wind sector responds to state aid more readily than solar. Figure 5 shows the relationship between revealed comparative advantage in wind turbines or solar cells, plotted against the domestic capacity for wind or solar electricity production. Table 1 provides the equivalent regression results for the relationship. The reader will note that relationship between competitiveness in wind turbine markets and the size of the market doesn't vary much whether relative or absolute measures of market size are used. In contrast, we find no relationship between market size and solar cell competitiveness for relative measures of the domestic solar energy market, but a marginally significant relationship when the market is measured in absolute terms.

While these numbers cannot be considered causal, they do point out that the size of domestic wind energy markets—whether measured in absolute or relative terms—is a much better predictor of global competitiveness in wind generation technology than in the solar energy sector. A Listian strategy of domestic market expansion in service of greater overseas competitiveness thus appears better suited to the wind industry.

[28] Historical feed-in tariff rates for wind and solar have reflected this. Both Germany and Spain, for instance, had much more generous tariffs for solar electricity, reflecting higher capital costs for solar cells. In the budget austerity that followed on the 2008-2009 financial crisis, these tariffs proved unsustainable and have been cut back substantially.

Exactly why this should be the case is unclear. One hypothesis, is that solar cells are more easily traded and therefore more prone to import competition than wind turbine. Thus given generous feed-in tariffs or other subsidies, countries may end up importing solar cell modules rather than purchasing them from domestic firms. Anecdotal evidence supports this argument. Germany is a net importer of solar cells. In 2009, Germany appears to have purchased approximately $18 billion in solar cells, of which $9.5 billion were imported, 40% from China. Meanwhile, Germany exported only $4.6 billion worth of solar cells.[29] Thus even though Germany was relatively competitive on world markets, its domestic support scheme was strong enough to draw in global imports. Something similar occurred in California in 2009-2010, when federal stimulus dollars for renewable energy investment appear to have purchased largely Chinese solar cells.

In contrast, wind turbines are difficult to ship, particularly in their newest, very large incarnations. The relatively higher cost of shipping and logistics may lead companies and countries to locate wind turbine production close to the point of installation, leading to greater development of domestic capacity and greater competitiveness on foreign markets.

An alternative hypothesis concerns skill formation. Solar cells use relatively common semiconductor manufacturing techniques, performing medium-value-add processes to standard and readily available inputs. In contrast, wind turbines contain significant tacit knowledge that has grown up via learning-by-doing processes, and draw on a range of sophisticated manufacturing techniques, materials, and supply networks. This difference in the skill and knowledge content of the two products may make solar cell production relatively easier to move to low-cost production centers compared with wind turbines.

[29] Calculations based on numbers provided by the UN COMTRADE statistics for total imports and exports, and BSW (2010) for domestic German production.

Figure 5: Fitted values and 95% confidence intervals for the regression of RCA on market size for both wind and solar electricity. Data on wind and solar electricity generation are taken from the Energy Information Administration as either billions of kWh or percent of total electricity generation. RCA values are computed from the UN COMTRADE data. All data are panel data for the period 1996-2008. Confidence intervals are estimated by bootstrapped standard errors clustered on country.

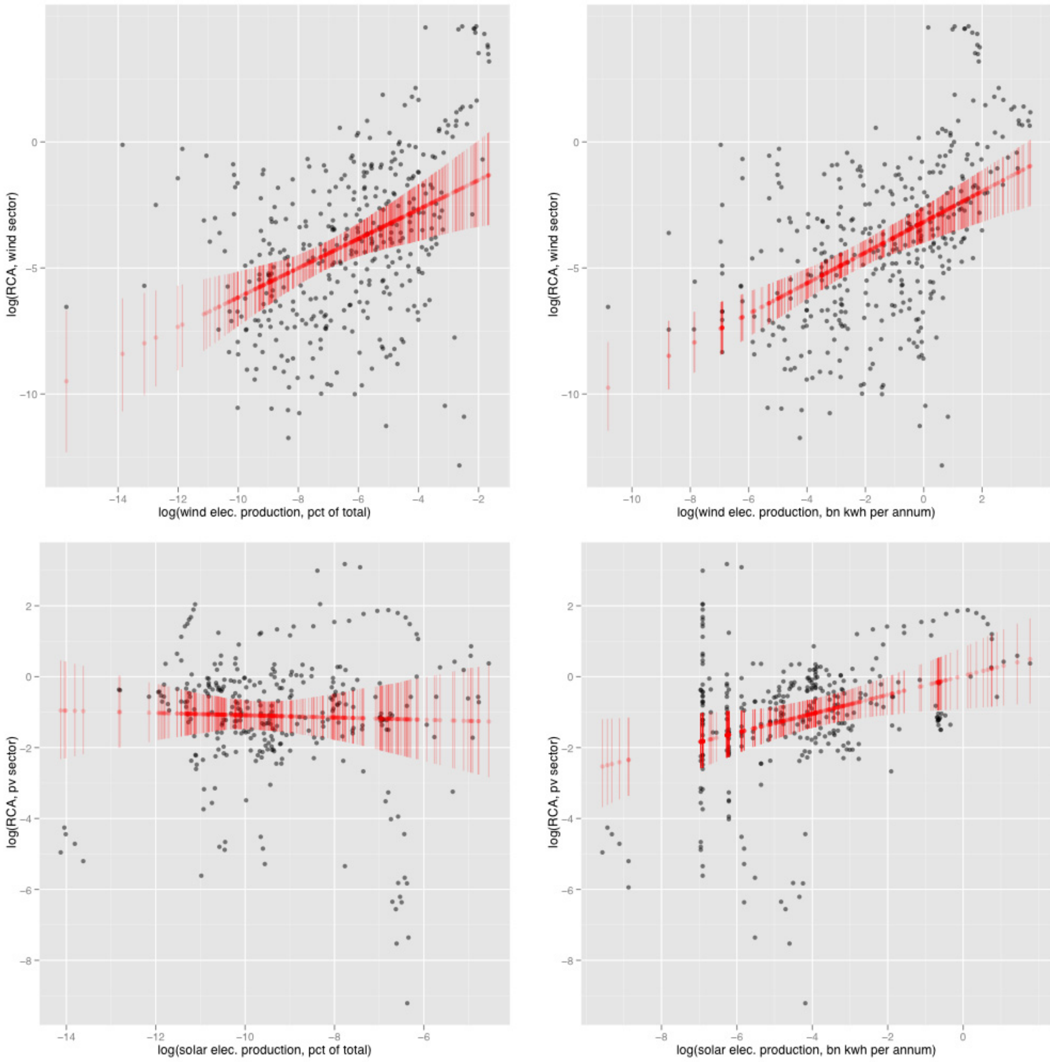


Table 1: Coefficients from the OLS regression of RCA in the wind or solar sector on the size of the domestic wind or solar electricity market. All data are by country, from the period 1996-2008. Confidence intervals are computed via bootstrap, clustered at the country level. Figure 5 shows the equivalent relationships and confidence intervals.

Market Size Measure	Intercept	Slope	CI, 95%, Intercept		CI, 95%, Slope	
Wind, pct. elec.gen	-0.305	0.588	-2.739	1.604	0.258	0.866
Wind, bn kwh	-3.145	0.615	-3.972	-2.519	0.375	0.801
Solar, pct.elec.gec	-1.354	-0.028	-4.108	1.618	-0.315	0.268
Solar, bn kwh	0.002	0.265	-0.931	0.792	0.058	0.447

5.4. Hypothesis 3: Path-dependent emergence of green industries

We saw that expanding domestic markets—possibly as a result of state aid—correlates with the development of export competitiveness in some sectors. This kind of correlation is broadly consistent with the economic policy arguments made in section 3, which explicitly link support for domestic markets in renewable energy goods to competitiveness in those goods abroad. But, for solar cells in particular, market size could not explain observed patterns of competitive advantage. Furthermore, consistent with Hidalgo et al (2007), we would not expect countries to simply launch entirely new sectors solely on the basis of expanding domestic markets. Other factors must have played a role for the location of this relatively new industry.

All forms of economic production carry with them skill and knowledge content. Moving into new sectors is made easier by competence in closely related industries, whose solutions to capital formation, skill development, firm relations, and other economic issues can be easily adapted to the new production chain. In the case of our 'green sectors', we want to understand whether prior expertise in 'supporting sectors'—those closely related in skill or content to 'green sectors'—can predict patterns of global competitive advantage in wind turbines or solar cells. This generates the following hypothesis: *countries with historically strong supporting sectors for green goods will do better in green industries than those without.*

We test this hypothesis by developing a measure of the strength of a country in the sectors supporting competitiveness in the 'green good'. This supporting sector strength RCA_{ss} is defined as the number of products close to the 'green good' with an RCA > 1. Closeness is defined as the proximity between the green and the other product (according to equation 3) being below some proximity threshold *P*. Countries that are more competitive in more goods proximate to our 'green goods' therefore display higher supporting sector strength. Formally, for each country *c* in year *y*,

$$RCA_{ss,y,c} = \sum_{(j|\text{prox}_{green,j} > P)} RCA_{j,y,c} > 1 \qquad (4)$$

We test whether the pattern of global competitiveness in good *green* in 2008 that's not explained by that same pattern in 1996 is correlated with $RCA_{ss,1996}$. To do this, we first regress $RCA_{green,2008}$ on $RCA_{green,1996}$. We then test the correlation between the variance not explained by this regression and the supporting sector strength $RCA_{ss,1996}$. Formally, we correlate the residuals from this regression with the strength of the supporting sectors, measured as the count of supporting sectors in a given country with *RCA* values greater than 1, for either wind turbines or solar cells. If our hypothesis holds, then knowledge of how countries compete in supporting sectors for 'green' products should improve our ability to predict future competitiveness in the 'green' sector itself.

This approach provides some means of controlling for persistent patterns of competitiveness in green sectors. We would expect patterns of competitiveness in a given industry to persist over time. If we were to ignore this and correlate today's patterns of competitiveness in green sectors with earlier patterns of supporting sector competitiveness, we might overestimate the importance of supporting sectors. Using only the residual variance in present green sector competitiveness provides some means of controlling for these persistent patterns. Note that this approach will not identify the importance of the supporting sector to maintaining comparative advantage in green goods over time. It only looks at whether changes in competiveness are correlated. Thus this is an implicitly *conservative* measure of the importance of supporting sector strength.

Figure 6 and Figure 8 show the relationship between past and present competitiveness in wind turbines and solar panels. Consistent with expectations, national competitiveness is quite persistent over time. , competitiveness is quite persistent with correlations of 0.62 for solar and 0.40 for wind.

Figure 7 and Figure 9 show the correlation of the remaining variance from that regression with the historic pattern of competitiveness in the green sector. For photovoltaics the competitiveness in supporting sectors in the past can partly explain the current strength in solar cells. For wind turbines this relation is also positive but not significant. [30]

Figure 6: shows the correlation between past and present export competitiveness in wind turbines;

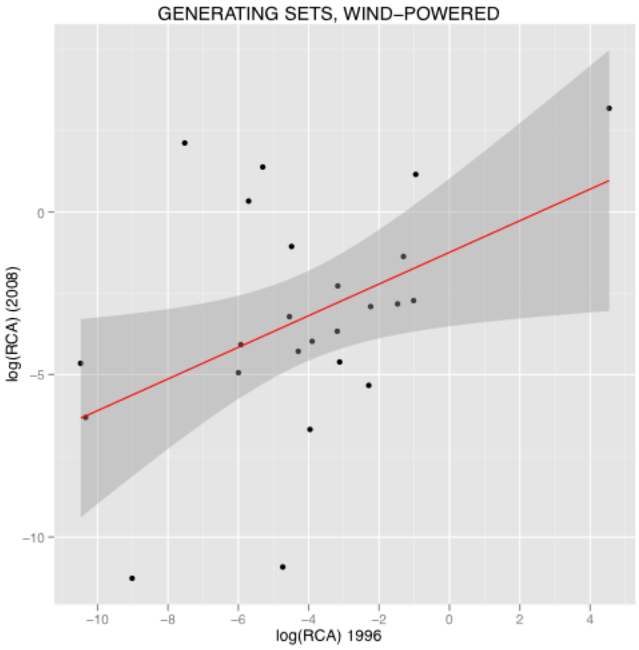


Figure 7: shows the correlation between the remaining variance and the density of a country's export competitiveness in proximate products in 1996. OLS regression overlaid in red with 95% CI.

30 Note that the 2008 data were used because they comprise a larger set of countries than the 2009 data, which were still incomplete at the time of this analysis. This should not affect the proximity values, as it would take country trade out of both the numerator and denominator of the RCA values.

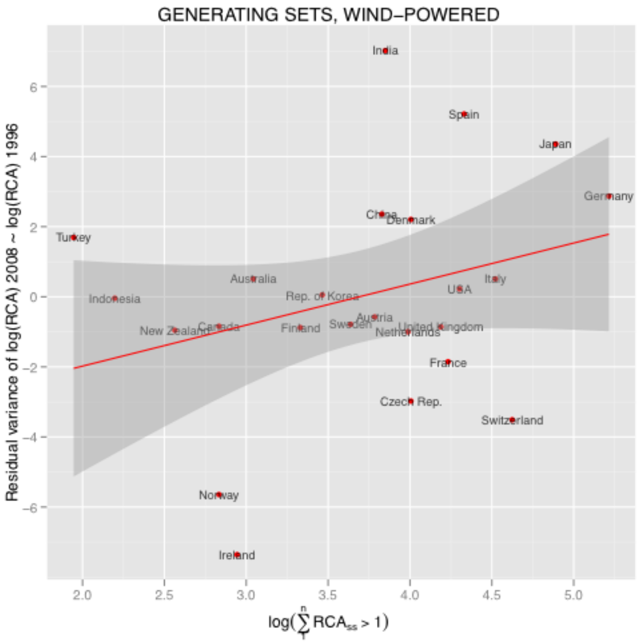


Figure 8: shows the correlation between past and present export competitiveness in solar cells;

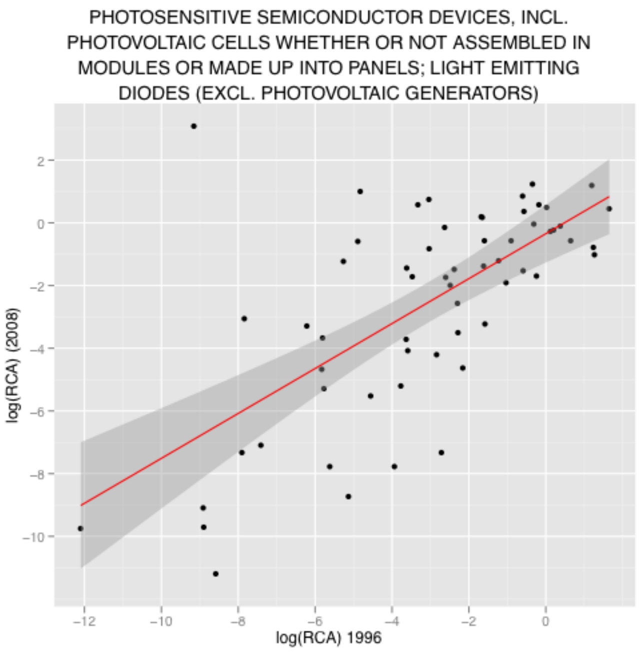


Figure 9: shows the correlation between the residual variance and the density of a country's export competitiveness in proximate products. OLS regression overlaid in red with 95% CI.

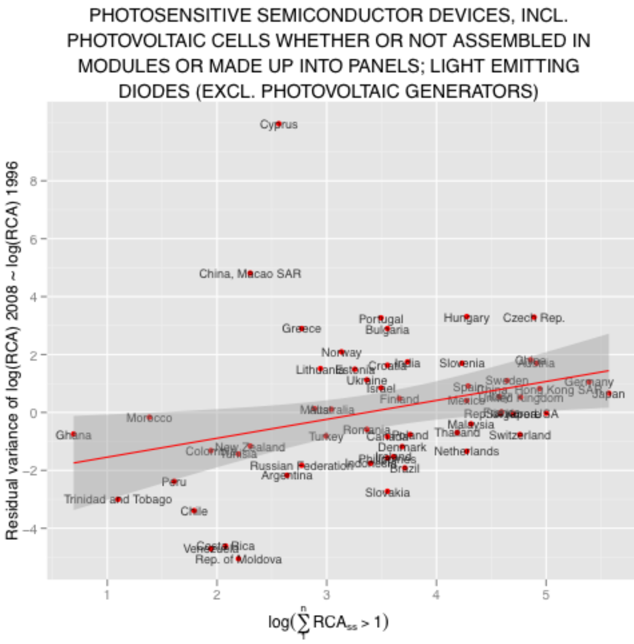


Table 2 and Table 3 quantify the correlations between present competitiveness in green sectors and each of these two measures. Table 2, corresponding to the data in Figure 6-9, shows that success in green goods is highly and significantly correlated with the density of a country's competitiveness in goods proximate to the green good in the product space. Table 3 shows that countries with historic strengths in goods proximate to the green good in the product space are more likely to later develop competiveness in the green goods themselves.

Table 2: Spearman rank correlation tests for the relationship of 2008 *RCA* values for green goods with the 1996 RCA value for equivalent goods. Corresponds to the data presented in Figure 6 and Figure 8.

Product	Spearman rho coeff.	p-value
Wind turbines	0.40	0.06
Solar cells	0.62	0.00

Table 3: Spearman rank correlation of residual variance of 2008 *RCA* values for green goods with earlier competitiveness in supporting sectors. Supporting sectors are defined as goods with proximity to the green good of 0.3 or higher. Earlier competitiveness is defined as count of those goods for which a country had an RCA > 1 in 1996. Residual variance is taken from the log-log regression of 2008 RCA on 1996 RCA. Corresponds to the data presented in Figure 7 and Figure 9.

Product	Spearman rho coeff.	p-value
Wind turbines	0.29	0.17
Solar cells	0.39	0.00

It is possible that the higher responsiveness on supporting sector strength of solar compared to wind is an artifact of the data. There are far fewer globally competitive exporters of wind turbines. As noted above, these turbines have traditionally been harder to ship than solar cells due to their size. Thus the data represent a fairly small sample of global economies, which will dilute the strength of correlations. Furthermore, the two-step approach (i.e., first eliminating the effect of past competitiveness and then correlating the residual to the current sector strength) might have unintended consequences. Consequently, we proceed with jointly testing the effects at the end of this section.

Several outliers deserve mention. Spain (in wind) and Portugal (in solar cells) have both achieved *RCA* levels above those we would expect from their performance in supporting sectors.[31] Spain aggressively promoted renewable energy as both an environmental initiative and an economic development strategy. Portugal engaged in significant energy market reforms at EU behest, in addition to more aggressive national measures (Rosenthal 2010).

For wind turbines in particular, Figure 7 and Figure 9 would suggest that these proactive policy measures have pushed these countries' revealed comparative advantage in wind turbines much higher than nations with comparable supporting-sector *RCA* values. Indeed, both countries are on par with levels of competitiveness achieved by Denmark and Germany, which appear to have much stronger supporting sectors. However, as both Spain and Portugal have encountered fiscal difficulties in the aftermath of the 2008 financial crisis, they have begun to withdraw or scale back ambitious green energy industrialisation programs. Whether these industries can now survive in the absence of either significant state support or strong surrounding networks of firms and capabilities remains unclear.

But Germany and Denmark remain the most successful European examples of using state support to develop internationally competitive firms in renewable energy industries. Yet they did so on the basis of historically strong supporting sectors in engineering, high-precision machining, and manufacturing. Their aggressive promotion of domestic markets for wind and solar energy built atop these existing foundations.

Finally, we test whether all three effects—domestic market size, historical competitiveness in the green sector, and competitiveness in the supporting sectors—together yield similar results. We use logistic regression of the form[32]:

$$RCA_{green,2008} = \alpha + \beta_1 RCA_{green,1996} + \beta_2 RCA_{ss,1996} + \beta_3 MktSize_{2008}$$

Here, RCA_{green} has been transformed into a binary variable coded as 1 if the RCA was greater than 1, and 0 otherwise. Countries reporting no *RCA* in the green sector were treated as having an *RCA* of zero—equivalent to no export of the green good in question. $RCA_{ss,2008}$ as introduced in equation 4 is the number of products close to the corresponding green good with an RCA greater one. $MktSize_{2008}$ is the absolute size of the market for the corresponding green good.

Table 4 and Table 5 show the results for both regressions. In both cases, supporting sector strength was found to have a significant effect on future competitiveness in 'green' sectors. We can thus confirm the earlier correlation result that early competitiveness in the supporting sector is a good predictor for current competitiveness in the 'green sector'. The fact that this relationship is also significant in the case of wind points is reassuring. Furthermore, consistent with the findings in section 5.3, market size—itself a proxy for state aid—supporting domestic competitiveness in wind turbines but not solar cells.

Table 4: Logistic regression of wind sector competitiveness on prior competitiveness, supporting sector strength, and domestic market size. Dependent variable was coded 1/0 based on RCA > 1 decision rule.

31 Portugal appears as an outlier in the 2008 data, but not in 2005-2007 or 2009. 2010 data is not yet available.

32 Due to the limited data availible we are unable to include interaction terms that would allow formally testing if state-support is most efficient if supporting sectors already exist.

	Estimate	Std. Error	z value	p-value	Sig. level
Intercept	-5.33	1.36	-3.93	0.00	99.9%
$RCA_{wind,\ 1996}$	10.33	3956.18	0.00	1.00	
RCA_{ss}	0.04	0.02	2.37	0.02	95.0%
MktSize	54.14	20.29	2.67	0.01	99.0%

Table 5: Logistic regression of solar sector competitiveness on prior competitiveness, supporting sector strength, and domestic market size. Dependent variable was coded 1/0 based on RCA > 1 decision rule.

	Estimate	Std. Error	z value	p-value	Sig. level
Intercept	-3.26	0.61	-5.36	0.00	99.9%
$RCA_{solar,\ 1996}$	-0.98	1.10	-0.89	0.37	
RCA_{ss}	0.03	0.01	3.70	0.00	99.9%
MktSize	-244.50	376.10	-0.65	0.52	

Finally, we note that these correlations depend heavily on the threshold value used to construct the supporting sectors (see Figure 11 in the Appendix). As the proximity threshold increases, the number of adjacent products included in the supporting sector falls rapidly. With that decrease comes a decrease in countries that report exports for those products. The overall drop in the number of sectors and countries results, by threshold sizes of 0.5, in very small sample sizes (on the order of 10 countries and 4-8 products). A threshold value of 0.3, used to produce the data in Figure 6 -9, provides a reasonable sample of the local product space around each of the goods in question.

6. Discussion

We were able to find various conditions that correlate with the development of a competitive advantage in solar cells and wind turbines. To different degrees, market size, early presence of the sector and the presence of supporting sectors is correlated with future competitiveness. With the available data, strict causality or an assessment of the interaction of the individual effects is hard to establish. However, we are able to show that the data are not inconsistent with the view that: (1) state support triggered market size expansion, (2) building on past strength in the corresponding sector and adjacent sectors this market size expansion triggered the development of global competitiveness.

Consequently the examination of the product space and its historical development suggests that developing export competitiveness in RES-E turns out to be as problematic and path-dependent as for other goods. Moving into sophisticated engineering and manufacturing industries like photovoltaics or wind turbines requires significant physical and human capital assets, production know-how, and firm expertise. Successful countries in green products today are either those who were successful in the past; or those who moved into those sectors from positions of strength in closely related sectors.

EU policy is predicated on the idea that expanding domestic markets for renewable energy will contribute to the establishment of competitive advantage in world markets. Hence the implied link between the pursuit of binding targets for renewable energy in the EU member states and spillovers for the competitiveness of European firms in world markets. But as we have seen competitiveness is about more than just domestic markets. Rather, competitiveness depends on the economy's ability to marshal complex sets of skills, capital, supply chains, infrastructure, and institutions to achieve high productivity.[33] Thus we may not expect that

[33] For example the work of Porter (2000) suggests that clusters advance through four dimensions (1) strong and sophisticated local demand; (2) a local base of related and supporting industries exist in the local economy to support the export industry; (3) favorable factor (resource) conditions; (4) a competitive climate driving firm productivity.

expansion of domestic markets alone, as EU energy policy anticipates, will create competitiveness in renewable energy industries, let alone growth.[34]

These findings pose challenges for the goal of using renewable energy policy to generate growth across the member states. The diversity of economic structures, institutions, patterns of economic production, and other factors informs against the idea that the Danish and German successes are widely replicable. Instead, the emphasis on renewable energy promotion as the primary means to de-carbonise the economy may reinforce pre-existing patterns of competitiveness. This has implications for European economic policy. The support of renewable electricity generation in Europe may create a larger market for competitive producers but not necessarily lead to the development of a competitive industry in the installing country. Therefore, it may even reinforce existing disparities between the member states.

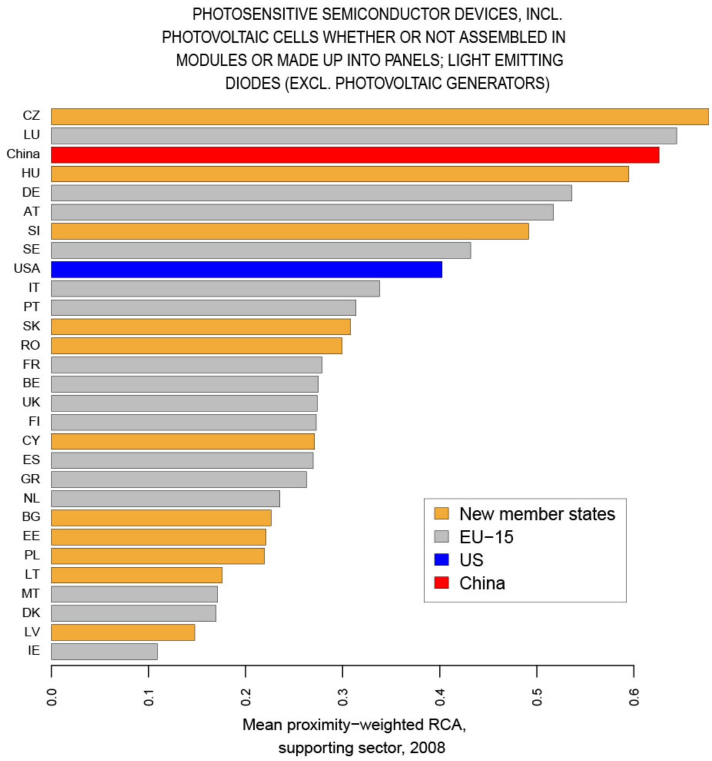
However, anecdotal evidence at least suggests that while EU countries should not all expect to become leaders in green technology as a result of the renewable energy standard, they may obtain spillover benefits from those that do. Examination of the Vestas supply chain shows that, while production is centered in Denmark, significant components of the generator, blades, control systems, and towers are sourced from elsewhere in Europe.[35] The improvement of the common market for energy-related products should improve the competitiveness of existing firms in green energy markets, and in doing so improve the prospects for their supplier networks throughout Europe.

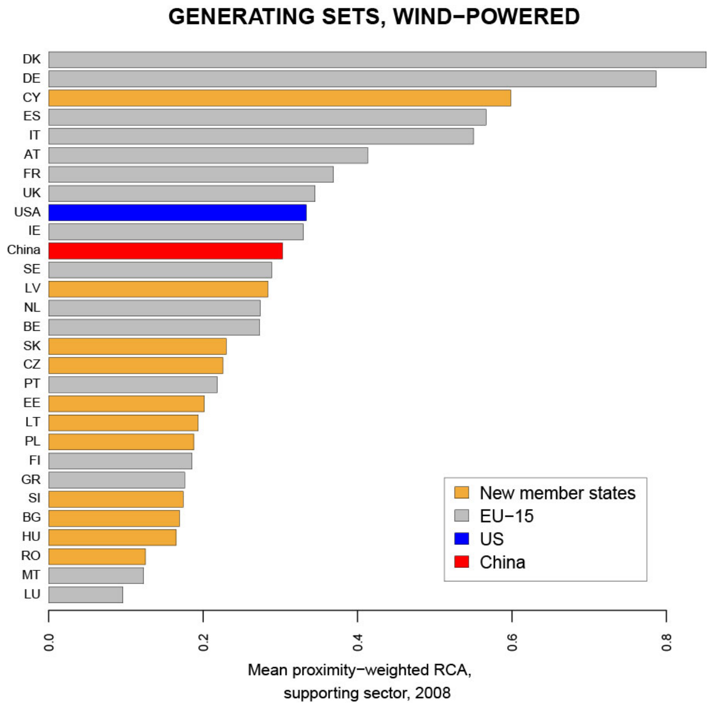
Figure 10 shows the rather substantial differences that exist in the strength of the supporting sectoral networks for wind and solar technology across the EU the US and China. So if industrial policy makers are 'doomed to choose' (Hausmann and Rodrik, 2006) than existing strength in supporting sectors suggest that choosing solar will be a less obvious choice for Denmark or Poland than it might be for the Czech Republic or Hungary.

[34] We abstain from analysing the link between the green sector and the entire economy. We only note that developing competitiveness in a set of sectors using policy instruments might at worst hinder growth by artificially shifting production factors from more to less productive sectors.

[35] See Husted (2006).

Figure 10: Mean *RCA* of the supporting sectors for solar cell production and for wind turbine production by country, 2008.





To be clear at the end, our study does not imply that renewable support passes the Bastable Test. We make no claims about whether state aid to renewable energy industries will generate sectors capable of repaying the costs of state intervention. Rather, we only argue that the chance of passing this test is higher—and thus the case for industrial policy stronger—in countries with stronger pre-existing conditions for success in these industries. That claim should lead to skepticism that 'green growth' can, as the EU and other policy actors argue, come primarily through the mechanism of expanding domestic markets for green goods.

7. Conclusions

Clearly this does not tell the entire story of developing export competitiveness in green goods. Further work is needed on the interaction of the different drivers for competitiveness; the complementarity or substitutability of links between green goods and different products; the evolution of green sectors over time; the role of cross-border value chains in spreading growth externalities from green industries in one country to supporting sectors in neighbouring countries; and the impact of the support for renewable energy on internal growth and not just export competitiveness.

But this work does suggest limits to popular arguments that link greater domestic consumption of green goods to export-led growth. Those countries that have done so successfully—Denmark and Germany first among them—started from highly advantageous domestic positions and achieved first-mover advantages. Second-tier followers, particularly in eastern Europe, will face intensified overseas competition and domestic economies lacking many of these advantages. Improved markets for low-emissions energy may aid greenhouse gas reduction and energy security. But the case for coupling these gains to economic growth via improved export competitiveness will – if ever – only be adequate for selected economies.

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9. Appendix

Figure 11: Density of proximity values to six green products over time. The green product space is averaged over the global product space estimates for 2005-2009. Presented separately, the proximity density to the green products varies relatively little over that period, suggesting that averaging helps mute volatility but does not fundamentally change the composition of the product space.