Green Exports and the Global Product Space: Prospects for EU Industrial Policy

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1 Introduction

Starting in the 1990s, motivated by high oil prices and environmental concerns, several European governments began to sponsor the widespread deployment of renewable electricity generation. Many of these countries have enjoyed significant spillover benefits for their economies. In Germany, for example, the renewable energy sector created 280,000 jobs by 2008 and was responsible for a domestic turnover of €31 billion.[3] In Denmark, wind energy alone accounted for 8.5% of total exports, employed 24,000 people, and produced € 7 billion in turnover.[4] These benefits have come in addition to reduced dependence on energy imports and reduced pollution. They have also helped sustain enthusiasm for green energy and emissions reduction.[5]

The European Union has now embarked on a similarly ambitious plan for renewable energy deployment. The 2009 Climate and Energy Package set ambitious targets for emissions reduction and renewable energy penetration by 2020. These targets were reiterated in the Europe 2020 document.(The European Commission, 2010) In setting out the long-term economic strategy for the European Union, this document established three justifications for renewable energy: greater security of supply, reduced greenhouse gas emissions, and improved national competitiveness in "green" energy technologies.[6] Competitiveness in particular has become a prominent part of the policy debate. 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."[7]

This paper asks whether this new initiative will succeed at replicating German and Danish success across the EU. Global competitiveness develops out of a range of factors. In high-technology sectors in particular, it depends on the ability of the economy to develop the skills, capital, resources, supply chains, and institutions necessary to organize high-productivity production competitive on world markets. Policy plays an important role in structuring the legal, regulatory, and market framework – for example by creating local demand for the products of new sectors - in which these factors develop. But using policy to create new sectors in the absence of favourable initial conditions may prove extremely expensive.

We find that economies with globally competitive renewable energy sectors built those sectors on the basis of pre-existing foundations of related skills, infrastructure, and institutions. Far from using policy to build entirely new industries, the most successful of the global green energy economies used policy to transfer pre-existing strengths to new but related sectors. Hence solar energy industries, for instance, grew out of expertise in microelectronics and semiconductors.

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[3] "Im Jahr 2008 erzielte der Sektor einen Inlandsumsatz von rund 31 Milliarden Euro und zählte rund 280.000 Brutto-Beschäftigte." [BMWi 2010].

[4] Danish Wind Industry Association, "Annual Statistics 2010" at http://www.windpower.org/en/knowledge/statistics.html.

[5] 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].

[6] "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)

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

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-carbonize the economy may reinforce pre-existing patterns of competitiveness.

2 Renewable energy and growth

Renewable energy industries are seen as attractive targets for industrial policy. Domestically, the energy sector has typically obtained significant state aid to build and operate the complex infrastructure required for a modern energy system. As states worry more about the cost and stability of imported fossil fuels, and the environmental damage their use causes, renewable energy provides a potential response. If support for renewable energy could translate into international competitiveness in high-technology industries, as it has in Denmark and Germany, it would generate spillover effects that could justify significant public and private investments in emissions reduction and low-carbon energy.

Table 1: Market share of top 10 Wind companies

1. Vestas (Denmark)	12.5%
2. GE Energy (United States)	12.4%
3. Sinovel (China)	9.2%
4. Enercon (Germany)	8.5%
5. Goldwind (China)	7.2%
6. Gamesa (Spain)	6.7%
7. Dongfang (China)	6.5%
8. Suzlon (India)	6.4%
9. Siemens (Denmark / Germany)	5.9%
10. REpower (Germany)	3.4%

Source: BTM Consult [http://www.reuters.com/article/idUSTRE62S12620100329]

European Union policy clearly envisages such a link. The 2009 Climate and Energy Package, the 2020 goals, and the Third Energy Market package all invoke growth, along with security of supply and emissions reduction, as justifications for concerted state action to support renewable energy and the infrastructure improvements it will require.

But each of these documents remain vague on exactly how investments in more expensive forms of energy will lead to growth. Most arguments imply one of four theories:

1. **Keynesian demand stimulus**
   In the aftermath of the 2008-2010 financial crisis, several political actors called for state spending in renewable energy as a form of economic stimulus. This occurred in the United States, under the American Recovery and Reinvestment Act; in the European Union; and in more ambitious plans for state investment in green technology, such as the European Green Party's "Green New Deal" program
2. **Improvement in terms-of-trade via decreased energy imports**
   The cost of dollar-denominated fossil fuel energy imports has been a significant concern to many economies since the shocks of the 1970s. This was among the most significant of the original

motivations for states like Denmark to pursue renewable energy policy, and remains of concern for Europe, particularly for petroleum.

3. **Increased innovation in response to greater administrative constraint**
Otherwise known as the "Porter Hypothesis", which argues that companies will respond to constraints on energy sources with a new wave of investment and innovation, generating a new range of products and services that form the basis for growth.
4. **Industrial policy targeted at growing export sectors**
Classical industrial policy arguments would suggest that a global market for green energy has recently established itself due to demand growth in Europe, the United States, and Asia; and that concerted sponsorship of domestic renewable energy sectors can lead to early mover advantages and hence export-led growth.

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. If growth is to be the goal, then it will come through mobilization of idle resources, investment and innovation, or the capture of world markets for goods.

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 competitiveness is about more than just domestic markets. Rather, competitiveness depends on the economy's ability to marshall complex sets of skills, capital, supply chains, infrastructure, and institutions to achieve high productivity. [8] Thus we may not expect that expansion of domestic markets alone, as EU energy policy anticipates, will competitiveness in renewable energy industries, let alone growth.[9]

3. Research design

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. 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 formalize and quantify networks of related products and track the evolution of those networks over time. Furthermore, consistent with Hidalgo and Hausmann (2010), 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 hypothesized supporting sectors, we can watch the emergence of

[8] 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.

[9] 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.

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.

3.1 Defining the product space

Consistent with Hidalgo et al. (2007), we define the product space as the matrix *P*, containing the proximities $p_{i,j}$ 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

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

Given the *RCA* values for countries *c* and goods *i*, we compute the proximity matrix as

$$prox_{i,j} = \min(p(x_j \mid x_i), p(x_i \mid x_j)) \tag{2}$$

$$p(x_j \mid x_i) = \frac{\sum_c RCA_{c,j} > 1 \mid RCA_{c,i} > 1}{\sum_c RCA_{c,i} > 1} \tag{3}$$

Equation 2 generates a symmetric proximity matrix of dimension $n \times n$, for *n* globally traded goods. As equation 3 indicates, we define a country to have "competitiveness" in a good if that country's exports of that good are a larger share of its overall exports than the similar ratio for world exports. The proximity is then 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 $p_{i,j}$ and $p_{j,i}$ to ensure that countries which are sole global exporters for some good do not dominate the calculation of proximity values.

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.[10]

The product space provides a latent representation of the relationships between competitiveness in different sectors. How exactly those relationships should be characterized remains the subject of some

[10] 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 8 in the Appendix). This provides some confidence that the observations that follow are not based on the idiosyncratic choice of dates.

dispute. Earlier analysis of industrial policy in the *filiere* tradition emphasized the importance of strategic sectors—as opposed to skills or capital or other abstract factors—for comparative advantage. 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.[11] 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.

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 specialize in are linked, not to specific historical expertise in one or several sectors, but to the institutional relations among labor, 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—emphasizes the institutional ability to reallocate labor and capital among closely related but highly exposed sectors on the basis of factor formation, not prior specialization.(Katzenstein 1985)

3.2 Data

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. Instead, we use the HS-6 product data from the United Nations COMTRADE database, for years 1990-2009. At the six-digit level, it becomes possible to identify a range of products usually classified as "green",. We define green products in the following categories: solar cells; wind turbines; nuclear power plants and parts thereof; and electric meters.[12]

Unlike the original paper, use of 6-digit data does not permit restriction of the goods that classify the product space. Hidalgo et al. (2007) find that only 775 of the 1006 goods defined in the 4-digit SITC product classification represent the entire product space. But at finer levels of granularity, we cannot observe that behavior. Hierarchical clustering of the proximity matrix does not reveal a set of unrelated goods that can be excluded from the resulting product space.

3.3 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. The Minimum Spanning Tree (MST) provides a visual reprentation of the product space matrix. If we define each product as a node in a tree, and the distances (ie, 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 minimized. Thus the MST for the product space illustrates the products space using the highest-proximity connections between products. The result is a

[11] Hidalgo and Hausmann (2010) 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.

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

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.

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.

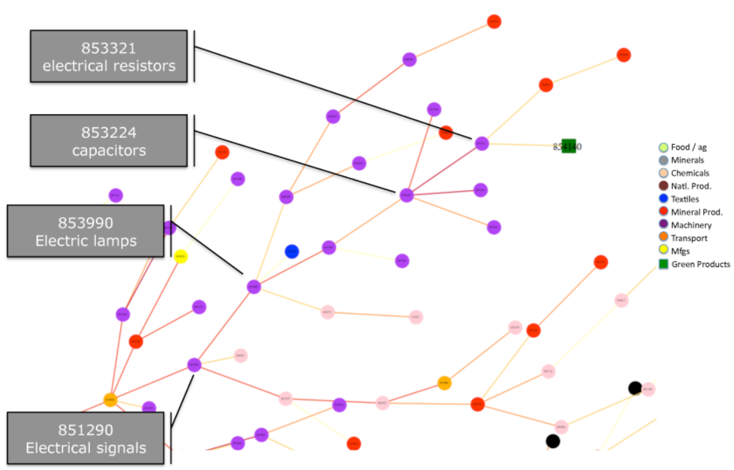
4 Results

We can learn a great deal about the prospects for green growth by observing the product space and the location of green products inside it. For the green growth question, we want to determine four things:

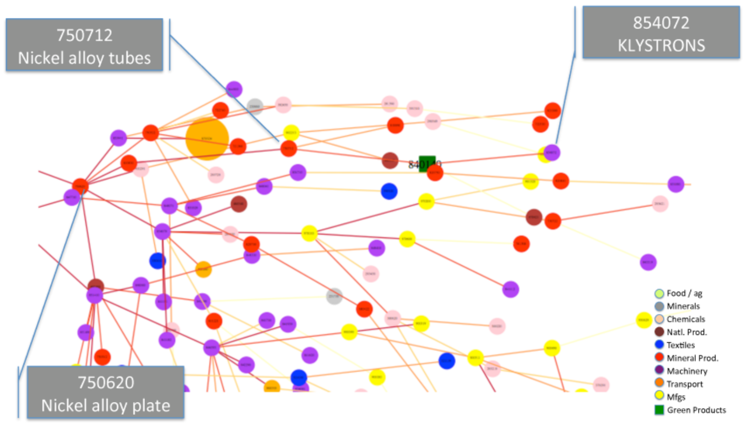
1. Are green products significantly different from non-green products; and if so, what does that tell us about patterns of green sector evolution?
2. Can we detect the antecedents of green sectors in the evolution of the product space?

4.1 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.



(a) The local solar cell product space



(b) The local nuclear power plant parts product space

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

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 specialized 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.

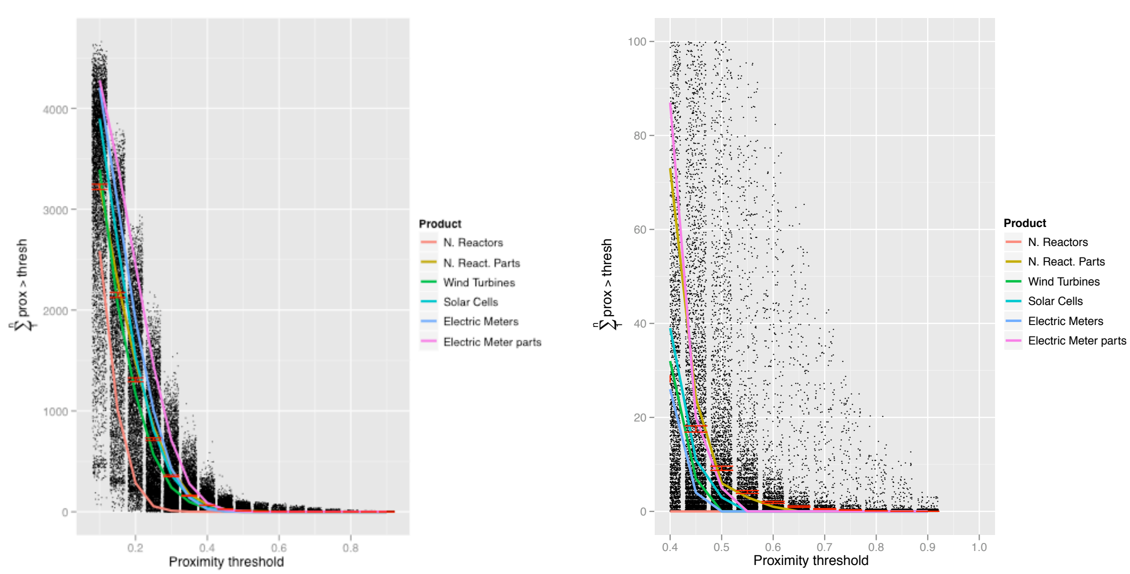


Figure 3: Density of proximity values in the product space. Points represent the count, for each product, of adjacent goods within some proximity threshold. Green products are shown in colored lines. Error bars show the 95% confidence intervals around the mean for each threshold.

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.

4.2 The emergence of green product competitiveness

If green products are not systemically different than their generic counterparts, this raises the question of whether a green industrial policy can transcend the normal problems faced in industrial and sectoral transition. 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. This observation 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 in two ways. First, we define a measure of competitiveness density D around a good g^* as the count of products $g \in G, g \neq g^*$ in a supporting sector SS_{g^*} within some proximity threshold p^* of good g^* with an RCA > 1. This is implicitly a measure of the density of a country's prior competitiveness in products identified as related to the green product in the product space. Formally, for each country c in year y,

$$SS_{g^*} = G_{g \neq g^*} \mid p_{g,g^*} > P$$
$$D_{c,g^*,y} = \sum_{SS_{g^*}} RCA_{c,y} > 1 \qquad (5)$$

We then test whether the pattern of global competitiveness in good g^* in 2008 that's not explained by that same pattern in 1996 is correlated with $D_{g^*,1996}$. To do this, we first regress $RCA_{g^*,2008}$ on $RCA_{g^*,1996}$. We then test the correlation between the variance not explained by this regression and the density measure $D_{g^*,1996.}$ If our hypothesis holds, countries with greater density in the product space surrounding the green product should develop better competitiveness in the green product over time.

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 4 (left) and Figure 5 (left) show the relationship between past and present competitiveness in for wind turbines and solar panels. Obviously, competitiveness is quite persistent with correlations of 0.62 for solar and 0.40 for wind.

Figure 4 (right) and Figure 5 (right) shows 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. [13]

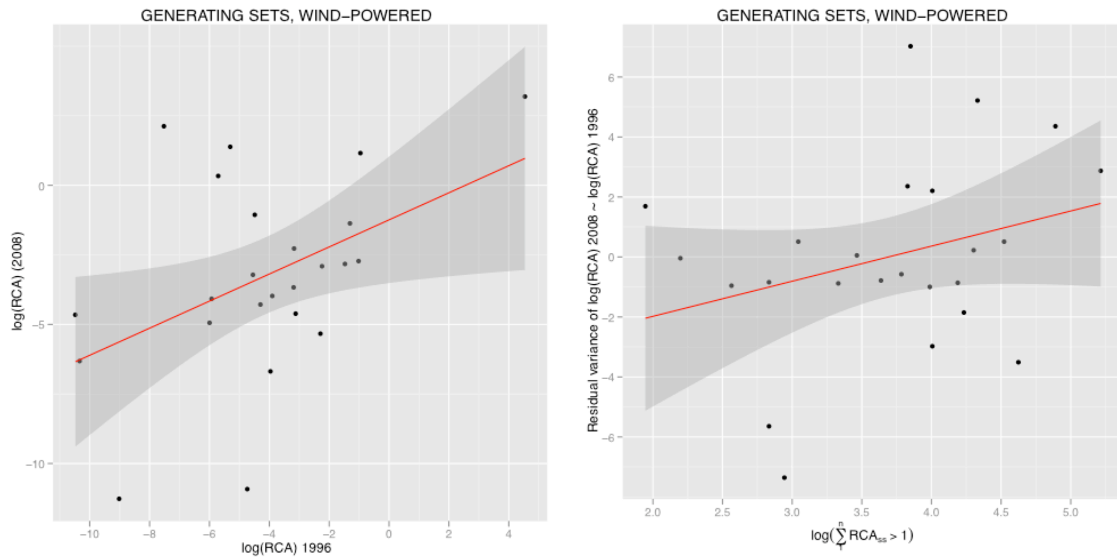


Figure 4 (left): shows the correlation between past and present export competitiveness in wind turbines; Figure 4 (right) shows the correlation between the remaining variance and the density of a country’s export competitiveness in proximate products in 1996. OLS regression overlaid in red with 95% CI.

Figure 5 (left): shows the correlation between past and present export competitiveness in solar cells; Figure 5 (right) 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.

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[13] 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.

As a second test, we take the top 500 products by *RCA* value for each country in 1996. For each green product, we sum the proximity of these top 500 products in the 2005-2009 product space. Again, we expect that higher total proximity values should correlate with stronger *RCA* for green products in 2008. But whereas the first test was retrospective, this test looks forward from historic national strengths to later outcomes. Figure 6 shows that this relationship holds again. States with strong green products sectors in 2008 were strong in closely related sectors in 1996. Those that were not, did not develop strong sectors.

Several outliers deserve mention. First, negative incentives appear to retard the growth of green industry. Poland, for instance, which has historically preferred to develop indigenous coal reserves, has achieved subpar *RCA* values for both wind and solar technology. The lack of domestic markets may therefore impede the development of these industries.

Second, and more encouraging for the green growth hypothesis, Spain and Portugal have both achieved *RCA* levels for wind turbines far above those we would expect from their performance in supporting sectors.[14] 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 6 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, it approaches the level of international export competitiveness in wind turbines 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 industrialization 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 cases of renewables-driven "green growth". Both countries benefitted from 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.

[14] Portugal appears as an outlier in the 2008 data, but not in 2005-2007 or 2009. 2010 data are not yet available.

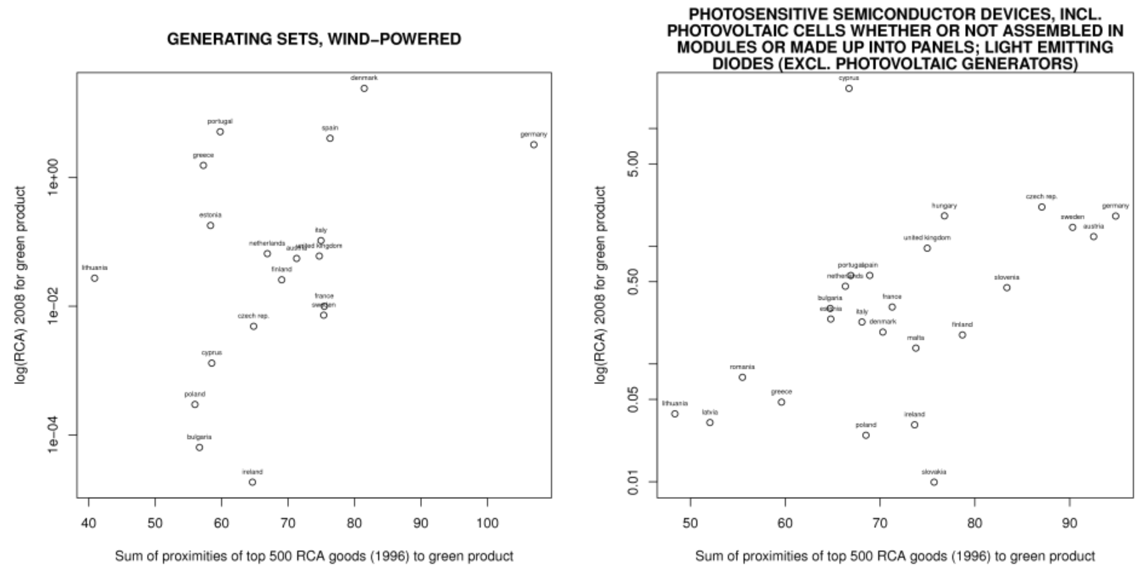

Figure 6: Test 2 (EU Countries): Correlation between the proximity to green products of leading industrial sectors in 1996, and 2008 green product *RCA*.

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 4 and Figure 5, 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.

These relationships are somewhat less clear for nuclear reactors and electrical meters than for wind turbines or solar power. The lack of many significant exporters for the nuclear reactors does not permit strong tests of these relationships for nuclear power. Correlations are also less clear for gas and electrical meters, though here the HS-6 data does not permit us to disentangle next-generation "smart" meters from legacy metering technology that has changed little in a century.

Product	**Spearman rho coeff.**	**p-value**
Wind turbines	0.40	0.06
Solar cells	0.62	0.00
Nuclear reactors	-0.27	0.39
Nuclear reactor parts	0.71	0.00
Electrical meters	0.69	0.00
Electrical meter parts	0.69	0.00

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 4 (left) and Figure 5 (left).

Product	**Spearman rho coeff.**	**p-value**
Wind turbines	0.29	0.17
Solar cells	0.39	0.00
Nuclear reactors	0.26	0.51

Nuclear reactor parts	0.72	0.00
Electrical meters	0.05	0.71
Electrical meter parts	0.23	0.09

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 taken from the log-log regression of 2008 RCA on 1996 RCA. Corresponds to the data presented in Figure 4 (right) and Figure 5 (right).

	All Countries		*EU-27 Countries*	
Product	**Correlation**	**p value**	**Correlation**	**p value**
Wind turbines	0.31	0.03	0.33	0.14
Solar cells	0.65	0.00	0.43	0.03
Nuclear reactors	0.36	0.13	0.34	0.29
Nuclear reactor parts	0.49	0.01	0.53	0.05
Electrical meters	0.04	0.71	0.14	0.50
Electrical meter parts	0.33	0.01	0.35	0.08

Table 4: Spearman correlation of 2008 *RCA* values for green goods with the proximity of past leading sectors in the economy. Leading sectors are defined as the top 500 goods for each country by RCA value in 1996. Proximity is defined as the sum of the proximity values for this set of goods for the green good in question. Corresponds to data presented in Figure 6.

Finally, we note that these correlations depend heavily on the threshold value used to construct the supporting sectors (see Figure 9 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). But for non-nuclear sectors, a threshold value of 0.3, used to produce the data in Table 2 and Table 3, provides a reasonable sample of the local product space around each of the goods in question.

5 Path dependency and green growth: implications for European industrial policy

As section 1 noted, the European Union has explicitly invoked economic growth as a justification for pursuing intensified development of renewable energy industries and other "green" technologies. This has included both the protection of existing comparative advantage, and the development of export competitiveness in these industries for all European member states.

Examination of the product space and its historical development suggests that this goal may be difficult to achieve. "Green growth," defined as export competitiveness, turns out to be as problematic and path-dependent as normal growth. 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. This is particularly true for electrical components like solar cells and electrical metering equipment.

Thus the promotion of export competitiveness in renewable energy industries may not deliver economic solidarity for EU member states. Indeed, it may even reinforce existing disparities between the member states. Figure 7 shows the rather substantial differences that exist in the strength of the supporting sectoral networks for wind and solar technology across the EU. If the expenditures required to pursue renewable energy industrial policy yield positive returns in states with strong supporting sectors, and negative returns elsewhere, this will exacerbate the already substantial differences in export competitiveness in green industries observed in Europe today.

Rapidly developing international competition will only make this problem more difficult. To the extent that the new member states achieve comparative advantage through mid-level manufacturing expertise coupled to lower operating costs, they will face intense competition in green industries from China in particular. The Chinese government has moved its own solar and wind industries rapidly up the value chain, in part through the sheer scale of demand for energy in the Chinese economy, and in part through aggressive requirements for technology transfer coupled to massive subsidies of Chinese firms.[15] So long as Chinese labor costs continue to undercut those of the new member states, while delivering comparable products, green growth will prove very difficult.

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.[16] 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.

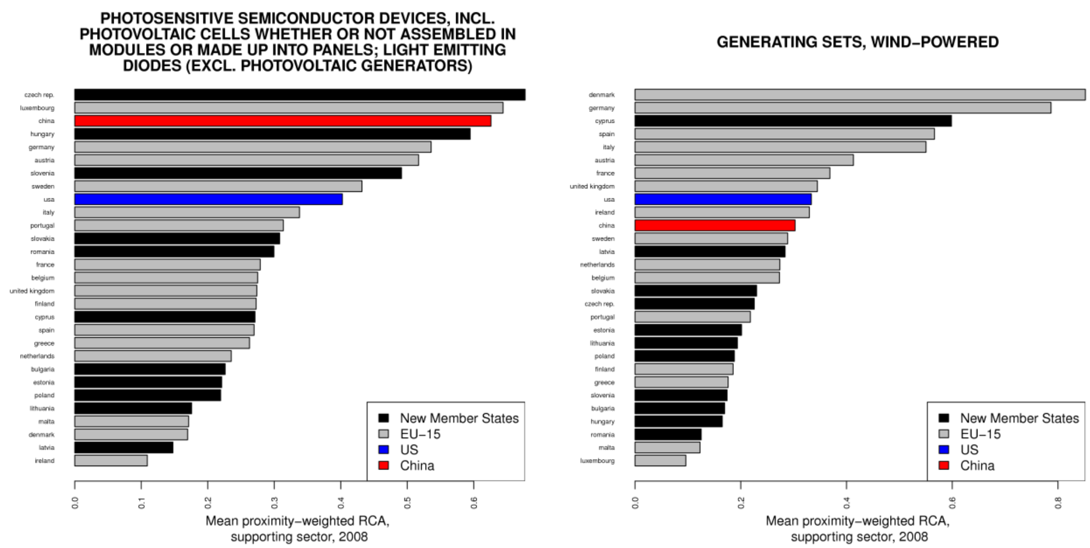

Figure 7: Mean *RCA* of the supporting sectors for solar cell production and for wind turbine production by country, 2008.

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[15] See, for instance, Bradsher (2010).

[16] See Søren Husted, President, Vestas Nacelles A/S, "Global production and sourcing strategy", 28 August 2006. Available at http://www.vestas.com/Files/Filer/EN/Investor/Capital%20Market%20Day/GlobalproductionandsourcingstrategyS%EF%BF%BDren_Husted.pdf. Referenced 7 January 2011.

6 Conclusions

Clearly this does not tell the entire story of renewable-energy-led growth. Further work is needed on 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.

Nevertheless, the core problems of growth remain regardless of its "greenness". If the European Union is serious about achieving broad-based growth through promotion of green technology and sustainable development, mere focus on the deployment of green energy is insufficient. Rather, the EU and its member states must continue to emphasize the enhancement of national abilities to generate technological innovation, train skilled workforces, invest capital strategically, and move into new markets in the presence of intense international competition. Absent convergence in these areas, pursuit of export competitiveness in renewable energy is no more likely to deliver economic solidarity or durable comparative advantage for the EU as a whole, than in any other industry. "Green growth," if it will come, will require a broader emphasis on reconciling the fundamentals of growth with the imperatives of environmental sustainability.

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Appendix

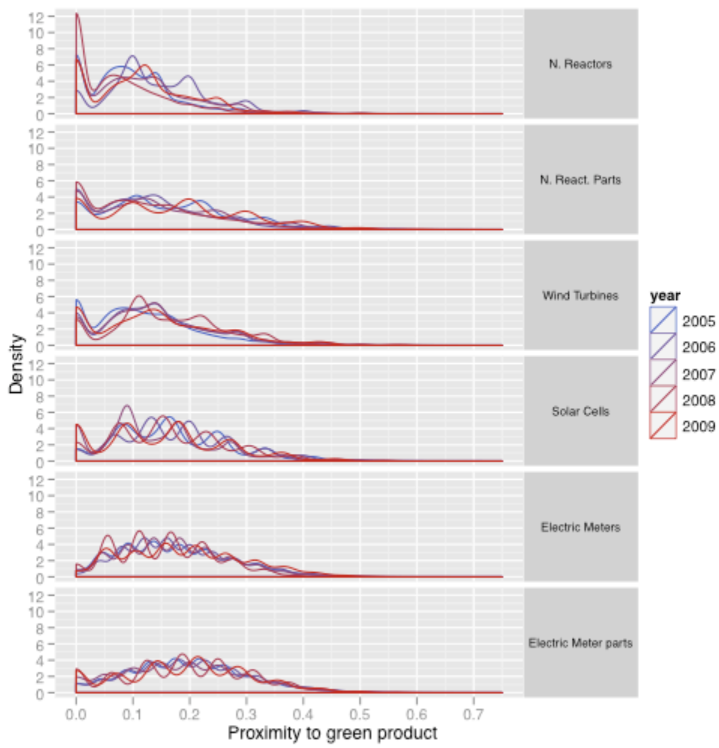

Figure 8: Density of proximity values to six green products over time. The green product space is averaged over the global product space estimates for 2005-2009. Presented separately, the proximity density to the green products varies relatively little over that period, suggesting that averaging helps mute volatility but does not fundamentally change the composition of the product space.

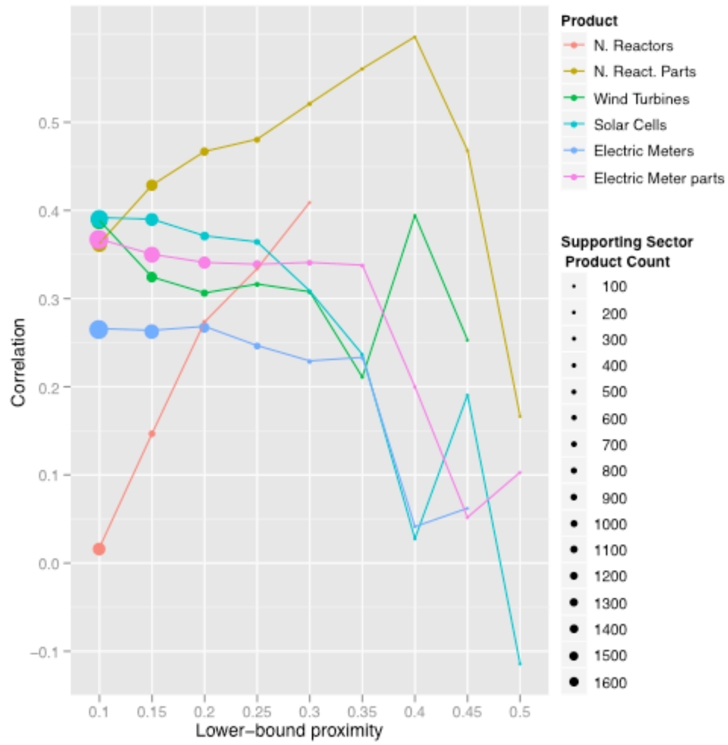

Figure 9: Change in correlation between the residual green sector competitiveness in 2008 and the strength of national supporting sectors in 1996. Data correspond to the analysis shown in figures 5b and 6b, and table 2.

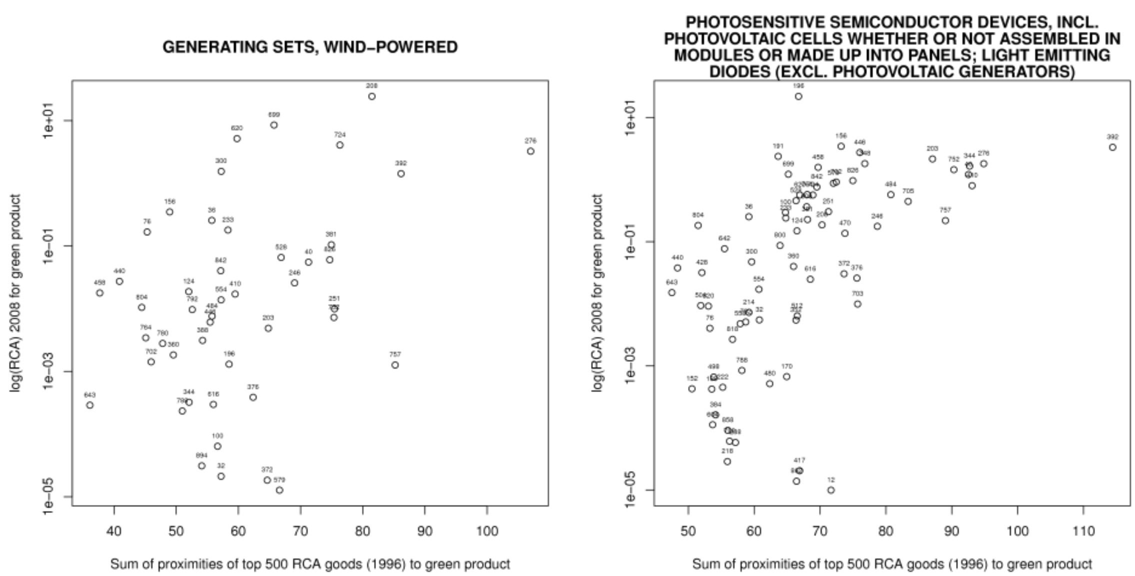

Figure 10: Test 2 (All Countries): Correlation between the proximity to green products of leading industrial sectors in 1996, and 2008 green product *RCA*.