Renewables' technological competitiveness and sustainable development in the new global economy

In the wake of the growing environmental and energetic crises, clean energy technologies gained much prominence over the past decade, but the need to meet tighter environmental standards has also been increasingly viewed as an important opportunity for recovery in the midst of the economic slowdown. Setting up conditions for the transition of the world economies to a "low-carbon" socio-economic "paradigm" of development has thus become a much bigger challenge which policy makers are expected to face. To fulfill such a target it is of crucial importance that energy and industrial policies are coordinated, as structural changes entailed by the transition to the new paradigm are highly demanding in terms of advances of the innovation systems. Inadequacy of the innovation systems not only precludes success in environmental innovation, but may also hamper growth dynamics leading further to loss of competitiveness, which equals to making development processes less sustainable

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Competitività tecnologica nelle fonti rinnovabili di energia e sviluppo sostenibile nella nuova economia mondiale

Nel corso dell'ultimo decennio l'aggravarsi dei problemi ambientali e la frequenza delle crisi energetiche hanno favorito le prospettive di sviluppo delle tecnologie per la produzione di energia da fonti non inquinanti. Ma con il sopraggiungere della crisi economica internazionale la necessità di far transitare le economie industriali verso un paradigma di produzione e consumo "a bassa intensità di carbonio" è stata sempre più valutata anche come un'opportunità per la ripresa della crescita ponendo i decisori politici di fronte a una sfida ancor più grande. Coordinare politiche energetiche e politiche industriali è fondamentale per il raggiungimento di questo obiettivo, poiché i cambiamenti strutturali richiesti dal cambiamento di paradigma menzionato necessitano della presenza di sistemi di innovazione avanzati. L'inadeguatezza dei sistemi di innovazione non solo preclude la possibilità di innovare nel settore ambientale, ma si riverbera in dinamiche di crescita economica più contenute, con ulteriore perdita di competitività, dando luogo così a processi di sviluppo meno sostenibili

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In the aftermath of the international crisis actions for sustainable development have become the object of renewed interest in policy discussions. As a matter of fact, making the concept of sustainable development operational for policies has always claimed complex synergies and trade-offs to be taken into account within the three dimensions - economic, environmental and social – of welfare addressed for growth. Over the past few years, the need to meet tighter environmental standards has been increasingly viewed as an important opportunity for recovery. Setting up conditions for the transition of the world economies to a "low-carbon" socio-economic "paradigm" of development has thus become a much bigger challenge which policy makers are expected to face and, in it, technological innovation in the energy sector is bound to play a major role. Most of the available options in low-carbon technologies, in fact, still have higher costs than those existing based on fossil fuels, and it is normally agreed that innovation is necessary in order to make them competitive.

With growing global economic interdependence, environmental technologies and knowledge have been increasingly exchanged across borders and a new division of labour has been devised along global value chains of bigger complexity due to the strengthening of the international production networks. Multinational enterprises (MNEs) have been crucial in shaping this process as they simultaneously embody the international transfer of capital, highly skilled labour, technology, and final and intermediate products. To an extent, the international crisis has put the vulnerability of such a global system to the fore, but the impact of the crisis on global value chains and drop in trade flows have proved to be neither straightforward nor clear. In fact, among the various causes which influenced trade dynamics, sectoral composition effects appeared to play a key role in inducing resilience to adverse shocks, with careful cost-benefit assessment of reducing production being determinant in the investment strategies.

In the wake of the growing environmental and energetic crises, clean energy technologies have gained much prominence over the past few years. Also, climate policies have proved decisive in starting such an unprecedented "technological transition", aimed at relocating trends of energy intensive industries. In particular, empirical evidence shows that world trade in renewable energy technologies outperformed that in manufacturing as a whole, while the impact of the crisis on it was comparatively less severe (Figure 1).

The analysis of world trade in renewable energy technologies thus allows to highlight the emergence of new patterns of international trade and comparative advantage in the energy sector while showing that a new world division of labour has been taking place despite the economic slowdown and right consistently with the demand for an "environmental technological transition".

Over the past five years, "second generation technologies" have proved to be the most dynamic component of international trade in renewables[1], with an average yearly increase of 25% (about twice as much that of the manufacturing as a whole), mainly determined by the dramatic growth of trade in photovoltaics (pv) among the more advanced technologies. Important differences also emerged at the regional level, as Japan and a large number of newly industrialized countries in their area of economic influence (including Nic's and Nec's), and China played a prominent role in the

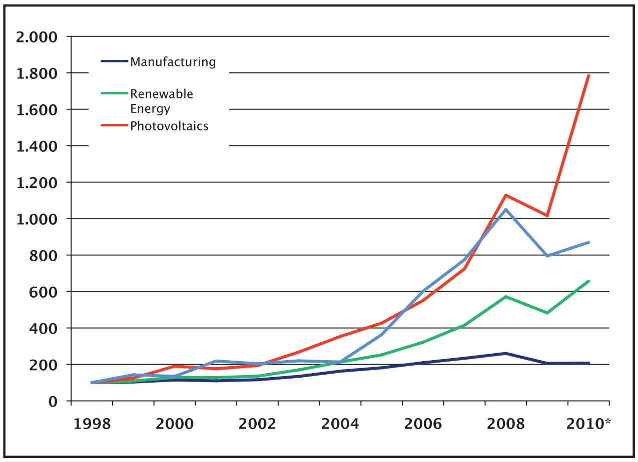

FIGURE 1 World trade: Manufacturing vs Renewables (Photovoltaics, Solar Thermal, Wind, Geothermal, Hydropower, Biomass)
Source: ENEA's Observatory on Technological Competitiveness elaboration from OECD-ITCS database

	1998-2000	2001-2003	2004-2006	2007-2009
WIND				
South-East Asia*	-0,85	-0,98	-0,74	-0,19
Russian Federation	-0,98	-1,00	-1,00	-1,00
Brasil	-0,53	-0,54	-0,88	-0,70
European Union (27)	0,39	0,40	0,37	0,28
United States of America	-0,76	-0,97	-0,68	-0,76
PHOTOVOLTAICS				
South-East Asia*	0,35	0,37	0,33	0,25
Russian Federation	-0,37	-0,75	-0,86	-0,91
Brasil	-0,77	-0,98	-0,99	-0,99
European Union (27)	-0,41	-0,46	-0,36	-0,22
United States of America	0,20	0,08	-0,02	-0,20
SOLAR THERMAL				
South-East Asia*	-0,80	-0,87	-0,80	-0,68
Russian Federation	-0,90	-0,82	-0,90	-0,98
Brasil	-0,94	-0,91	-0,91	-0,87
European Union (27)	0,19	0,14	0,20	0,22
United States of America	-0,14	-0,18	-0,22	-0,16

* Japan, China, India, NICs (Rep. of Korea, Chinese Taipei, Hong-Kong, Singapore) and NECs (Indonesia, Malaysia, Philippines, Thailand)
A country is defined as being specialized in exports of a certain product if its market share in that product x is higher than its manufacturing market share y.
The index is then normalized between -1 and +1:

$$IS = \frac{\frac{\chi}{1} - 1}{\frac{\chi}{1} + 1}$$

TABLE 1 Regional trade: Trade Specialization in Renewable Energy Technologies
Source: ENEA's Observatory on Technological Competitiveness elaboration from OECD-ITCS database

export of pv technologies (the total export share of all these countries for pv in 2010 was widely over 50%). However, looking at the whole dynamics of trade geography further significant aspects can be singled out once all the specific components of the "second generation" renewable technologies are considered (Table 1).

In fact Europe did partially catch up with pv exports while continuing to increase export shares in the other solar technologies. At the same time a significant increase of export shares emerged for wind power in Japan, China and India, at least up to 2009, when the total export share of these countries was over 23%. For 2010, on the contrary, we record a remarkable drop in that share, reaching a level below 5%, as a consequence of the sharp decrease in United States' imports (-48%) – the main external market for Asian wind productions – and, at least for China, of the strong growth of the internal demand.

The whole trade dynamics in "second generation" renewables technologies can be clearly related to the figures of investment flows in renewables technologies showed in the latest UNEP reports (2010 and 2011), as well as to the figures of foreign direct investment presented in the 2010 World Investment Report focusing on the various activities undertaken in the environmental field. Figures in these reports

are mostly aggregate and often heterogeneous from the point of view of both the nature of the investment typologies and the technological "profile" of the initiatives themselves. However, it turns to be quite evident that a huge effort has been made throughout all advanced and newly industrialized economies in order to tackle the "structural" transition to renewable energy, and that for this reason the trend of investment has been only slightly diverted by the effects of the economic meltdown.
Foreign direct investments have played even a more fundamental role as they paved the way to the development of renewable energy technologies in newly industrialized countries while boosting the activity in the environmental production and giving rise to that dramatic up-rise of export flows from these regions, which has been driving world trade in renewables technologies for the past four/five years. In fact, as stressed by the World Investment Report, they increasingly developed along a "North-South" trajectory until 2007, although they decreased dramatically after the economic meltdown had started. However, a significant recovery of total FDI flows has been recorded over the past year while an unprecedented outward investment dynamics has been singled out for the newly industrialized countries giving rise to investment flows of growing strength along "South-South" trajectories. As such, this seems to suggest that in the latest years the growth of renewable technology exports in the newly industrialized countries is rather the outcome of a renewed capacity of production as well as the premise of a built-in process of technological development.
As a matter of fact, the analysis of the patenting activity[2] points out that in these economies innovation processes in renewables technologies just started taking place in the latest period and that both solar and wind power technologies were significantly involved. In all these countries (including most Nics and Necs, China and India) patent shares in pv and wind power (Figure 2) appear to be still much lower than export shares (Figure 3).
Yet their trend is increasing and technological specialization is clearly emerging as far as wind power technologies are concerned.
In the case of wind power technologies a prominent role is being also played by the other two countries belonging to the BRICS group (Russia and Brazil), whilst further insights can be drawn from the analysis of the "off-shore" applications over the very recent period. In fact about 8% of total patents in the "off-shore" wind power are held by Brics countries (mainly China and Russia) in the 2007-2009 period, whereas technological specialization has been growing over time. However "off-shore" wind power has become an emerging technological niche for a large number of (often small) countries throughout the world in Europe, Asia and Efta countries, with a widespread distribution of patent shares across regions (Table 2).

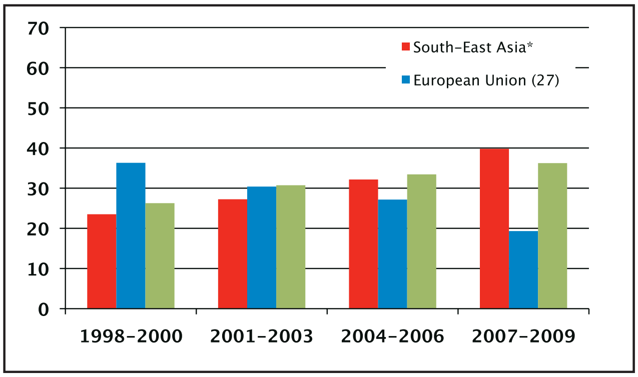

FIGURE 2 Photovoltaic technology – Shares in world patents
Source: ENEA's Observatory on Technological Competitiveness elaboration from OECD-ITCS database

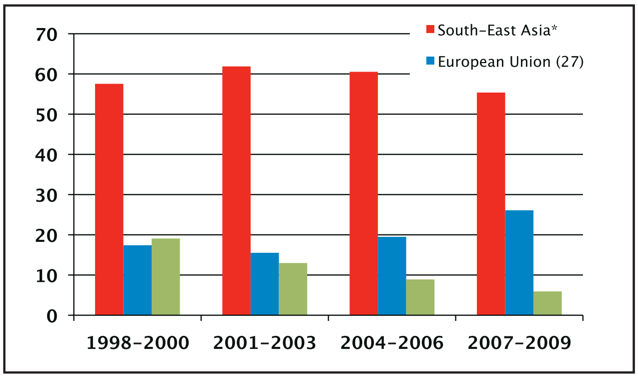

FIGURE 3 Photovoltaic technology - Export shares in world trade
Source: ENEA's Observatory on Technological Competitiveness elaboration from OECD-ITCS database

	1998-2000	2001-2003	2004-2006	2007-2009
SOLAR THERMAL				
European Union (27)	0,07	0,07	0,24	0,21
Norway	0,34	0,37	0,03	-0,20
Switzerland	0,34	0,05	-0,02	0,01
Israel	0,39	0,37	0,12	0,45
Australia	0,53	0,72	0,64	0,48
China	0,26	0,35	0,34	0,03
Russian Federation	-0,12	0,66	0,59	0,15
CONCENTRATED SOLAR POWER				
European Union (27)	-0,38	0,18	0,17	0,06
Switzerland			0,27	0,36
Israel	0,87		0,77	0,84
Australia		0,92	0,21	0,32
China				0,06
WIND OFF-SHORE				
European Union (27)	0,42	0,25	0,28	0,19
Norway		0,90	0,89	0,94
Australia			0,27	0,23
Rep. of Korea		0,11	0,18	0,11
China	0,27		0,17	0,09
Russian Federation		0,68	0,63	0,66
Brasil		0,59		0,26

A country is defined as being specialized in exports of a certain product if its market share in that product x is higher than its manufacturing market share y.
The index is then normalized between -1 and +1:

$$IS = \frac{\frac{\chi}{1} - 1}{\frac{\chi}{1} + 1}$$

TABLE 2 Patent specialization index for some renewable energy technologies
Source: ENEA's Observatory on Technological Competitiveness elaboration from Oecd-Itcs database

As far as European countries are concerned, wind power technologies are still fundamental in shaping their technological specialization in "second generation" technologies, but solar technologies - let aside pv - have grown much in importance over the most recent years involving an increasing number of countries. In pv technologies the European position is, instead, still lagging behind with only few countries holding significant patent shares. Germany and France hold the highest pv shares (4% and 8% in the 2007-2009 period) but they are still despecialized. Pv technologies are, in fact, a point of concern for Europe as the demand for pv energy soared over the most recent years, which was at the origin of deepening trade deficits in a large number of countries. The case is quite peculiar for Italy which ranked second in world pv energy production but increasingly enlarged pv imports and trade

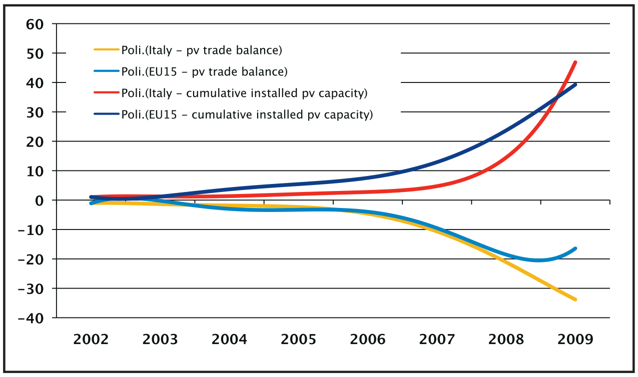

FIGURE 4 Italy and the pv balance-of-payment-constraint growth
Source: ENEA's Observatory on Technological Competitiveness elaboration from OECD-ITCS database and EurObserv'ER data

deficit despite the economic slowdown (Figure 4). In other terms, this shows how coordinating energy and industrial policies is crucial when tackling structural changes in the production system. It also seems to be a convincing explanation for the catching up process in pv technology development which is clearly shown by patent patterns in both a number of European countries and the United States since the second half of last decade.

More in general, it should be stressed that the capacity of technology to transform profoundly the whole economy lies in the characteristics of the changing network of interactions of all the socio-economic agents that contribute to innovations, also referred to as the *national system of innovation* (Lundvall, 1992). This means that conditions are to be set so as the *national system of innovation* induces an effective dynamics towards the radical change desired as implied in the Perez's view of *techno-economic paradigm* (Perez, 1983). In fact a *techno-economic paradigm* is "a *best practice model for the most effective use of the new technologies within and beyond the new industries. The new industries expand to become the engines of growth, for a long period while the techno-economic paradigm drives a vast reorganization across the economy* [...] *A techno-economic paradigm serves as an envelope encompassing and shaping the trajectories of individual technologies. Its influence extends from the business sphere to institutions and society so that it gradually becomes the shared common sense for decision making in management, engineering, finance and trade. This new logic and its capacity to increase effectiveness and efficiency eventually also shape institutional and social organizations, expectations and behavior*" (Perez, 2010).

When looking at "environmental innovations", one should consider that these may not be specifically disentangled from other types of innovations and from the full matrix of complex relationships associated with innovation dynamics and policies (see Jaffe 2003 and Mazzanti and Zoboli 2008 for recent developments). In fact, "environmental innovations" can be more often devised in a context of "double externalities", with on the one hand the typical technological (R&D) spillovers, and on the other hand the reduction of environmental externalities (Jaffe et al., 2005). Therefore, the emergence of an "environmental techno-economic paradigm" has to be addressed in terms of both the environmental objectives to meet and the characteristics of the national innovation system.

In order for the economy to react to changes induced by the "environmental constraint", national innovation systems must be equipped with adequate scientific and technological knowledge (Altman, 2001). Under "proper" conditions, the use of environmental measures (namely regulations and/or carbon pricing instruments) may even give rise to competitive advantages in environmental technologies (Porter and Van der Linde, 1995, and Costantini and Crespi, 2008, for recent empirical findings). In contrast, inadequacy of innovation systems not only precludes success in environmental innovation, but may also damp growth dynamics causing major divergences from virtuous paths of growth and leading further to loss of competitiveness. This kind of dynamics between growth, technical change and competitiveness has been well addressed by Kaldor (Kaldor, 1957), as he recognizes the importance of endogenously determined technical change and technological learning, while emphasizing the importance of expanding markets to explain the presence of increasing returns and "cumulative causation" growth thereafter.

In these terms, loss of competitiveness may in turn give rise to further loss of capacity of absorbing technical progress and, because of the "environmental constraint", failure to develop competitive environmental innovation can lead to further divergence in the patterns of growth.

Loss of technological competitiveness with tighter environmental standards may also give rise to a tighter balance-of-payment constraint (Thirlwall, 1979), which is the same as making development less sustainable (the aforementioned case of Italy in pv technologies appears to be quite emblematic of this problem. A comprehensive analysis of loss of technological competitiveness for Italy is presented in Ciriaci and Palma, 2008). This turns to be essential as far as the creation of "green jobs" is concerned and should be therefore taken into careful account if a sort of "green-growth" goal is to be accomplished. The existence of a significant balance-of-payment constraint hampers growth and targeting "green growth" without targeting a suitable goal of "technological competitiveness" may well give rise to job destruction rather than creation.

The emergence of new patterns of comparative advantage in renewables technologies as the global demand for clean technologies surges clearly points out that innovation in the energy sector is going to become crucial for supporting competitiveness and growth. With rapid technological catching up of the newly industrialized countries, the most advanced economies are going to face a much bigger challenge than in the first period of globalization. The new "multipolar" economy is, in fact, increasingly turned into a knowledge-based multipolar one where competitiveness is essentially based on innovation.

As reported by Victor and Yanosek in Foreign Affairs, "nearly seven-eighths of all clean-energy investment worldwide now goes to deploying existing technologies, most of which are not competitive without the help of government subsidies. Only a tiny share of the investment focuses on innovation". Rather, solutions for innovation "must start with more consistent long-term policies that depend less on subsidies and thus are less vulnerable to cutbacks in these time of fiscal restraint". This has been the story so far, and it will certainly be a point of big concern for western economies until their sovereign debts will continue to jeopardize investment policies.

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Notes

[1] Data on trade and patents are elaborated by ENEA's Observatory on Technological Competitiveness (ENEA-UTT).

[2] In the present work the analysis of patenting activity has been carried out through the Orbit database (a platform specialized in intellectual property) that allows much more accuracy in the selection of techniques as patent search can be run on both IPC codes and keywords for specific fields of technological applications .