

PED-329

Microeconomics of Competitiveness: Firms, Clusters and Economic Development

Germany's Photovoltaic Cluster

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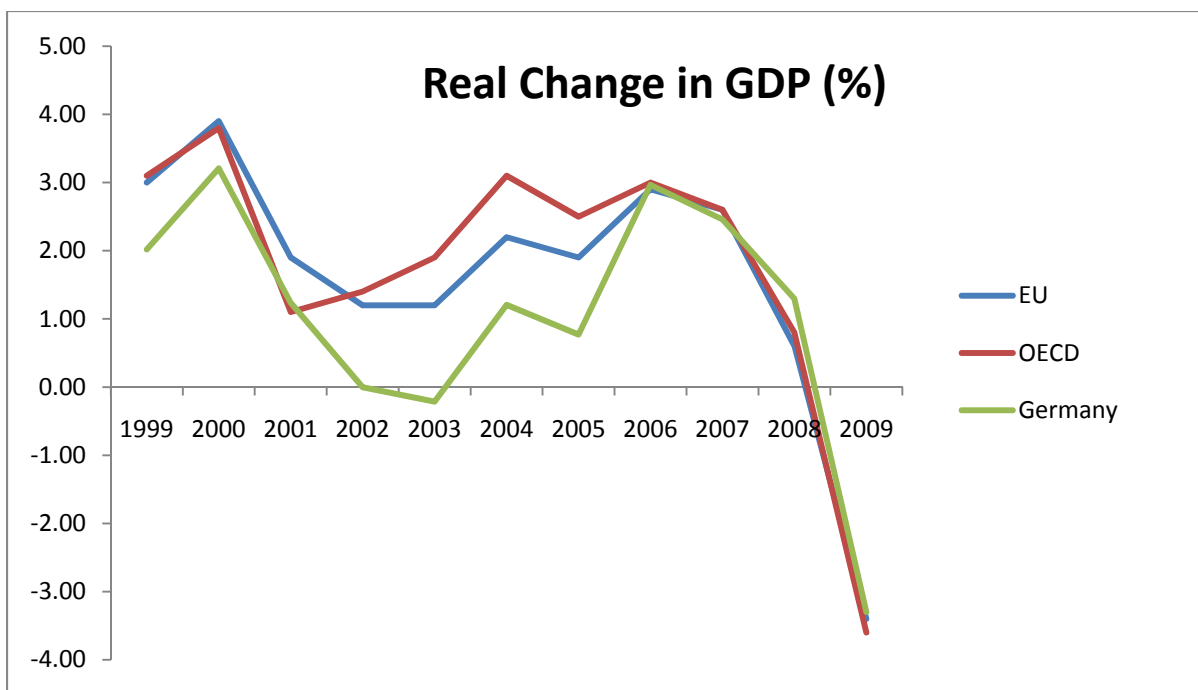
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1. COUNTRY ANALYSIS

1.1 Overall Economic Performance

The German economy is the fifth largest economy in the world in PPP terms (US \$2.7 trillion in 2008¹) and the leading economy in Europe. In 2007, services constituted 69.5 percent of GDP; industry and construction, 29.6 percent; and agriculture, the remaining 0.9 percent.²

Figure 1. GDP growth in Germany



Source: EIU data.

Strong growth in 2007 led unemployment in 2008 to fall below 7.8 percent,³ the lowest level since the reunification of Eastern and Western Germany.⁴ With 1.3 percent annual growth in 2008,⁵ however, the economy began to contract in the second quarter due to the strong euro, high oil

¹ EIU data.

² Library of Congress, Federal Research Department, April 2008.

³ EIU data.

⁴ Modernization and integration of the Eastern German economy continues to be a long-term process.

⁵ CIA data.

prices, tighter credit markets, and slowing growth abroad. The German economy is predicted to contract by 6 percent in 2009.⁶

There is a GDP per capita gap between states in East and West Germany, with East German states having a lower GDP per capita on average. East German states, however, are growing faster than West German states with the help of government incentives packages to encourage investment in the region.

Table 1. German Lander Nominal GDP Per Capita for PV Module Producing States

| Region | Lander | 2008 | 5 Year Growth |
|-----------------|------------------------|-------------|----------------------|
| East | Brandenburg | 21,721 € | 19.26% |
| East | Thuringia | 21,875 € | 20.05% |
| East | Saxony | 22,620 € | 17.89% |
| East | Saxony-Anhalt | 22,427 € | 23.46% |
| East | Mecklenburg-Vorpommern | 21,439 € | 19.73% |
| West | North Rhine-Westphalia | 30,113 € | 15.49% |
| West | Bavaria | 35,530 € | 15.37% |
| West | Baden Wurttemberg | 33,876 € | 14.75% |
| Germany Average | -- | 30,343 € | 15.72% |

Source: Statistical offices of the Lander and the Federal Statistical Office.

Budgetary Policy

From a budget deficit of about 4 percent of GDP in 2004, the economy reached balance in 2007.⁷ A substantial policy effort contributed to a structural adjustment of about 3 percent of GDP between 2003 and 2007.⁸ Much of this adjustment reflected cuts in discretionary, aging, and welfare expenditures. The adjustment continued in 2007 with the VAT hike, a reduction in the deductibility of interest income, expenditure restraint, and an increase in healthcare premiums.⁹ However,

⁶ Financial Times, "World in Recession: Berlin expects 6% contraction but snubs call for new stimulus," 30 April 2009, Asia Ed 1.

⁷ EIU data.

⁸ IMF country report, February 2008.

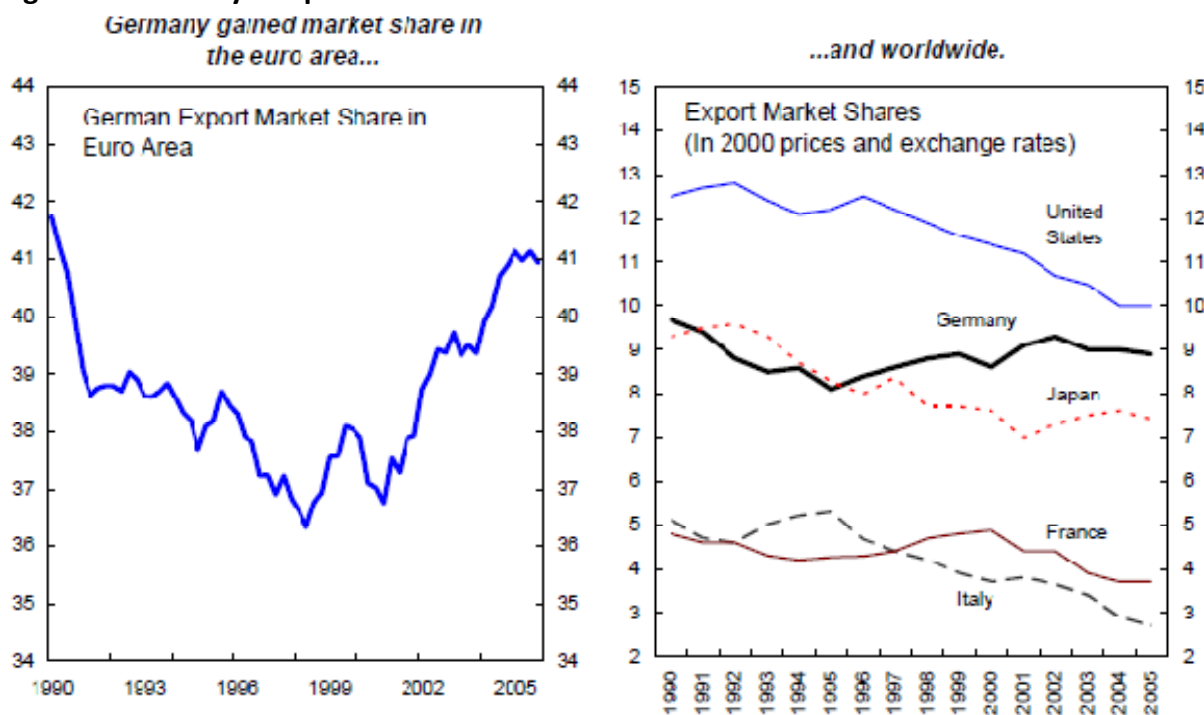
⁹ Ibid.

recent developments have led the government to revise fiscal policy with more countercyclical measures.

Domestic Demand

Even though consumers are feeling considerable relief from the recent oil price fall, hopes for a noticeable boost to consumption did not become reality. Wages rose in 2008 about 3 percent, in accordance with collective agreements.¹⁰ However, there are substantial job losses in the course of the recession and a rising savings ratio.

Figure 2. Germany's export market share



Source: WEO, OECD, Direction of Trade Statistics, and IMF staff calculations.

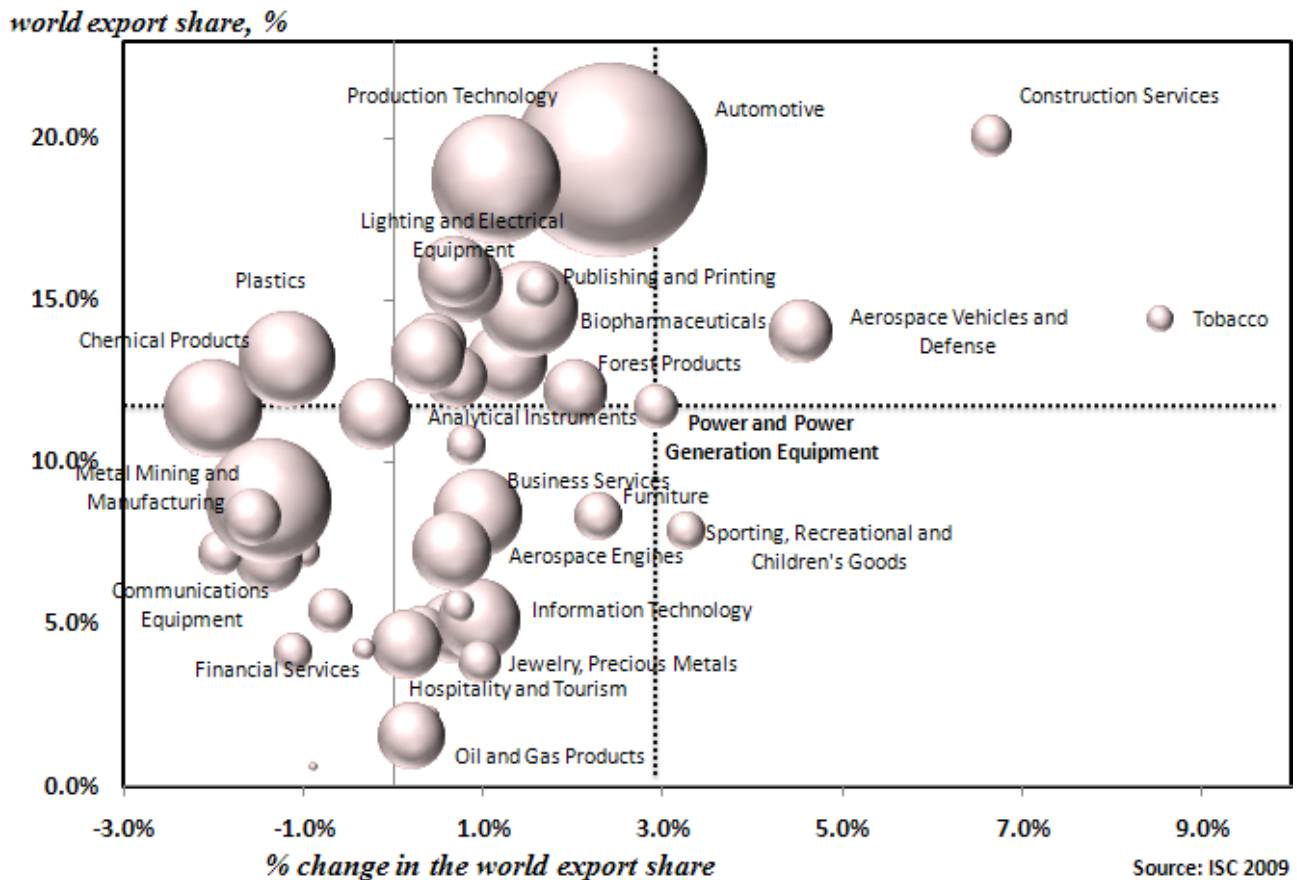
German external performance

The export sector's performance has been strong and the country's growth is being carried by net exports, while the domestic consumption remains weak. Improving competitiveness, rising external demand, and favorable trade linkages helped exporters to build market share. Exports of goods rose

¹⁰ Federal Ministry of Economics and Technology, Annual Economic Report 2008.

by more than 50 percent in real terms since the euro's inception in 1999.¹¹ Germany has been world's number one exporter since 2003. The current-account surplus has remained large at more than 5 percent of GDP since 2004¹², following deficits in the 1990s.¹³ This turnaround in the current account is the reflection of steady improvements in the trade balance, especially within the EU.

Figure 3. Exports Portfolio by Cluster, 1997-2007



In 2008, exports amounted to 47.2 percent of GDP, while imports were 40.9 percent. Germany's most important market is the European market¹⁴: European countries are the destination of 74 percent of German exports, while other European countries are the source of 71 percent of German imports.¹⁵ An immediate neighbor, France is its most important trading partner, accounting for 9.6

¹¹ IMF Country Report, December 2006.

¹² EIU data

¹³ EIU data.

¹⁴ Ibid.

¹⁵ German Federal Ministry of Economics and Technology.

percent of German exports in 2006.¹⁶ The United States ranks second at 8.7 percent.¹⁷ Of Germany's ten leading trading partners, which together account for about two thirds of Germany's foreign trade, only three - the United States, Japan and China - are located outside Europe.

Germany has strengthened its already strong position in the world. Most German clusters have grown and substantially increased their shares in the world export market between 1999 and 2007 (Figure 3).

In terms of foreign direct investment, Germany is a very attractive place. In 2008, it attracted EUR 460 billion and had operations of 45,000 foreign companies, including the world's 500 largest corporations.¹⁸

Table 2. Unemployment rate in Germany in 2003 (in percent)

| Unemployment rate (Eurostat/OECD definition) | |
|---------------------------------------------------|------|
| Germany | 9.3 |
| West ¹ | 7.3 |
| East ¹ | 17.5 |
| Structural unemployment rate (Nairu) ² | |
| Germany | 7.2 |
| West | 5.2 |
| East | 15.4 |

Sources: Mikrozensus (Statistisches Bundesamt) 2004; and IMF staff estimates.

¹ Staff estimates.

² Assuming that the output gap is similar in the East and West.

Unemployment

The distribution of Germany's workforce by sector has the following structure: agriculture 2.2 percent; industry 25.5 percent; and service, 72.3 percent, with total 39.1 million participants.¹⁹

Unemployment remains in double digits in some states in the East, where high wages are not

¹⁶ Ibid.

¹⁷ Ibid.

¹⁸ GTAI (2009) web-site: <http://www.gtai.com/homepage/germany-at-a-glance/facts-figures/our-economy/?backlink=0> [Accessed in May 2009].

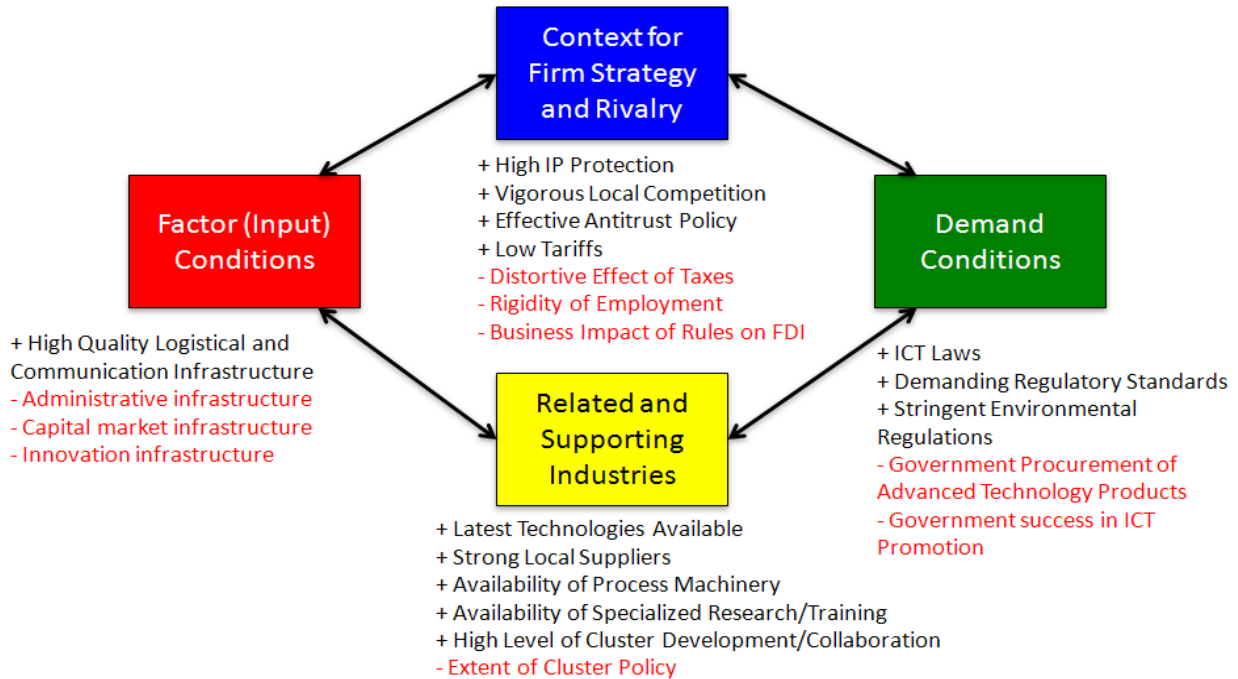
¹⁹ Library of Congress, Federal Research Department, April 2008.

matched by productivity. Germany's stagnation is widely viewed as a structural problem with its roots in the labor market. Overregulation has prevented the domestic economy from absorbing quickly the labor shed by the export sector. Wage rigidities and high reservation wages remain important impediments to employment creation, despite significant reforms. Given high labor costs and wage rigidities, companies stepped up their purchases of intermediate inputs from cheaper (mostly foreign) suppliers (outsourcing) and, at times, shifted entire production lines to lower-cost countries (off-shoring). As a result, high unemployment is an important problem in the German economy and fighting it has been a central focus of the government's reforms. Germany's labor market problems are concentrated in unemployment in the East, unemployment and non-participation among older workers nation-wide, and nonparticipation among women—particularly in the West—and young people.

1.2 National Business Environment

Figure 4 summarizes the strengths and weaknesses of the national diamond.

Figure 4. National Diamond Analysis



Source: Authors' analysis.

Factor Conditions

In terms of broad positive factor conditions, Germany has very high quality logistical and communications infrastructure. Germany has ranked second in the global ranking list for the number of patents per capita. Germany spends 2.5 percent of GDP²⁰ on research and development (R&D), which is quite a high level worldwide, though it is still less than in Japan and the US.

Apart from patents, the three broad areas where Germany is above its competitiveness rankings based on purchasing power parity-adjusted GDP per capita²¹ are administrative infrastructure, capital market infrastructure, and innovation infrastructure.²² Within innovation infrastructure, four targets that need the most improvement are (1) Quality of the educational system, (2) Quality of

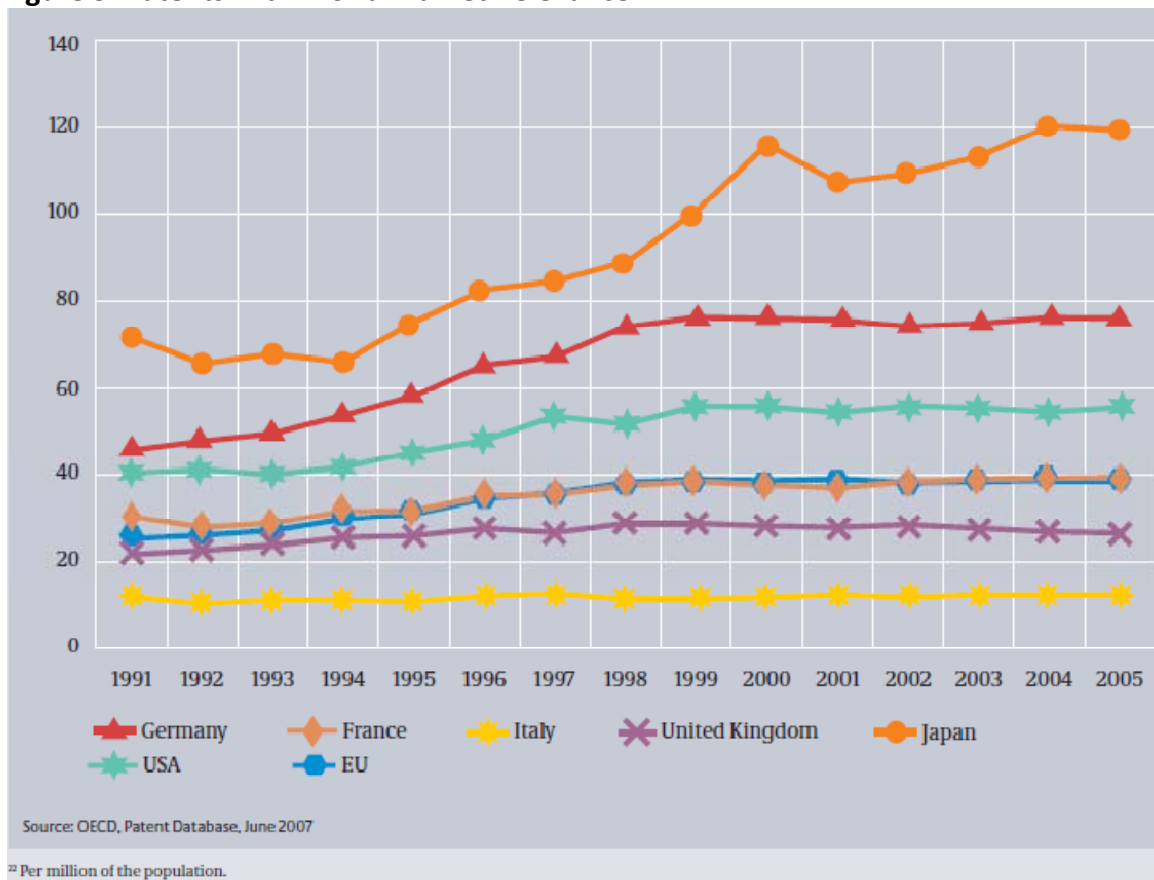
²⁰ World Development Indicators.

²¹ Above means doing poorly.

²² Rankings in 2008 Global Competitiveness Report.

math and science education, (3) Availability of scientists and engineers, and (4) Tertiary enrollment. In the education category, Germany's 2006 PISA reading and mathematics scores are even with the OECD average and science scores are above the average, but tertiary attainment in Germany is now below average. Even worse, the performance gap between native students and students with immigrant backgrounds is "one of the largest among OECD countries."²³

Figure 5. Patents with World Market Relevance



Within the capital market infrastructure, the three poorest indicators for Germany are (1) Ease of access to loans, (2) Financing through the local equity market, and (3) the Soundness of banks. In terms of the soundness of banks (which has been a global problem), the main problem with

²³ OECD Economic Survey of Germany, p. 96.

German banks is the €816 billion of toxic assets the Landesbanken (State Banks) hold.²⁴ In response, the German federal government is offering to create a bad bank to buy up the toxic assets provided that the banks agree to consolidate the state-owned banking sector.²⁵ Small and medium-sized businesses are the driving force of the German economy. The roughly 3.5 million small and medium-sized companies and self-employed persons comprise 99.7 percent of all businesses,²⁶ produce 40.8 percent of taxable turnover, provide 70.5 percent of jobs and train 83.4 percent of all apprentices.²⁷ Financing for small and medium-sized companies in eastern Germany is more difficult than in West Germany. The reserves and securities that are available for the purpose of securing loans are mostly smaller than for companies in western Germany. Due to significantly higher loan defaults in the past, banks are less willing than they were previously to accept credit risks.

Within the administrative infrastructure, the poorest indicators are (1) Ease of starting a new business, (2) Number of procedures required to start a business, and (3) Burden of government regulation. To address starting a business, the German government launched a Start-Up Campaign in 2006. An information system was placed online offering support for start-up consultancy services in 2006, electronic commercial registration was introduced for companies in 2007, and the minimum amount of capital required to start a limited liability company will be lowered to €10,000.

Demand Conditions

On average, Germany's rank in demand conditions is competitive compared to its PPP adjusted GDP per capita, but two indicators are particularly low in this category. First is the government procurement of advanced technology products. The second lowest performing indicator is

²⁴ Financial Times, 4 May 2009.

²⁵ *Ibid.*

²⁶ Chritian Rammer, United Nations University, Universiteit Maastricht, Country Review of Germany, The "POLICY MIX" Project.

²⁷ *Ibid.*

government success in ICT promotion. ICT now contributes more to value creation in Germany than automotive and mechanical engineering and it is estimated that ICT accounts for 40 percent of economic growth.²⁸ To address ICT promotion, the German government has created a program, Information Society Germany 2010, to maximize growth and employment in the sector.

Related and Supporting Industries

This is by far the strongest part of the German national diamond, with only the extent of cluster policy being a relative disadvantage for Germany. Even the ranking for the extent of cluster policy is only two ranks above the GDP ranking for Germany. The most visible cluster policy in Germany is currently the German government's High-Tech Strategy. This strategy, which began in 2006, focuses on 17 high-tech fields, such as health, security, energy, optical technologies, information and communication, and nanotechnologies. As part of the strategy, the German government aims to increase R&D expenditures to reach 3 percent of GDP.²⁹ Unfortunately, although most of Germany's clusters are high-tech, there are some fast-growing ones like tobacco and construction services that are not. For these clusters, there is no discernible cluster policy in Germany.

Context for Strategy and Rivalry

Germany's context for strategy and rivalry ranking is approximately as strong as its factor and demand conditions rankings, but far behind its related and supporting industries ranking. Within this category, Germany does particularly well in the intensity of local competition and the effectiveness of antitrust policy. There are, however, three indicators in which Germany does not

²⁸ German Federal Ministry of Economics and Technology, <http://www.bmwi.de/English/Navigation/Technology-policy/the-information-society.html>.

²⁹ EU 2008 assessment of progress on the Lisbon Strategy reforms, p. 24.

do well at all. These are: (1) Impact of taxation on incentives to work and invest, (2) Distortive effect of taxes and subsidies on competition, and (3) Rigidity of employment.

In terms of taxation, Germany implemented a corporate tax reform in 2008 to increase its competitiveness as a business location. This reform has reduced the corporate tax rate from 39 percent to below 30 percent.³⁰ In the 2007 Employment Rigidity Index, Germany scored 13 points above the high-income OECD average.^{31,32} The Hartz labor reforms implemented from 2002 to 2004 mainly focused on reducing high unemployment, but now Germany must turn to improving the competitiveness of its labor force.

1.3 National Level Recommendations for the German Government

Cross-cutting reforms

- Improving domestic consumption through promotion of domestic products
- Simplification of government regulations, particularly in the area of starting a business, while conducting further tax reforms to complement 2008 tax cuts
- Further restructuring of the financial market to facilitate easy access to loans while easing financing through equity market

Strategy and rivalry- labor market improvements

- Reducing rigidity of employment and expanding large-scale job training and placement programs
- Reduction of social benefits to increase incentives to work
- Relaxing immigration policy for high skilled labor

³⁰ German Business Portal, <http://www.german-business-portal.info/GBP/Navigation/en/Business-Information/legal-requirements.html>.

³¹ Above is worse.

³² World Development Indicators.

Innovation promotion

- Keeping policy of reaching 3% GDP expenditures on R&D and increasing government expenditure on advanced technology products to promote demand
- Attracting top-level researchers from abroad, expanding bilateral and multilateral scientific co-operation, offering attractive return options to German researchers
- Improving the education system at all levels, especially at the level of tertiary education in order to meet expected increases in the demand for highly qualified people.

2. PHOTOVOLTAIC CLUSTER ANALYSIS

2.1 Overview of German Photovoltaic Cluster

In 2007, Germany was the world's largest solar PV market with 3.8 GWp of total installed PV power, representing 49 percent of global market share.³³ The German cluster accounted for 55 percent of global solar electricity production and installed 1.1 GWp of new PV capacity in 2007 alone, generating EUR 5.7 billion in revenues (33 percent of the world market), including EUR 2.5 billion in exports.³⁴

The cluster boasted more than 10,000 businesses³⁵, including over 80 manufacturers of PV components, over 60 PV equipment suppliers, and employed 42,000 people in 2007 (denoting employment growth of over 30 percent since 2006).³⁶ The growth of the cluster has been buttressed by a strong focus on innovation and technology, with over 60 research institutes in Germany engaged in the development of PV technology. German investments in PV R&D

³³ GTAI (2009d).

³⁴ GTAI (2009d) and Wissing (2008).

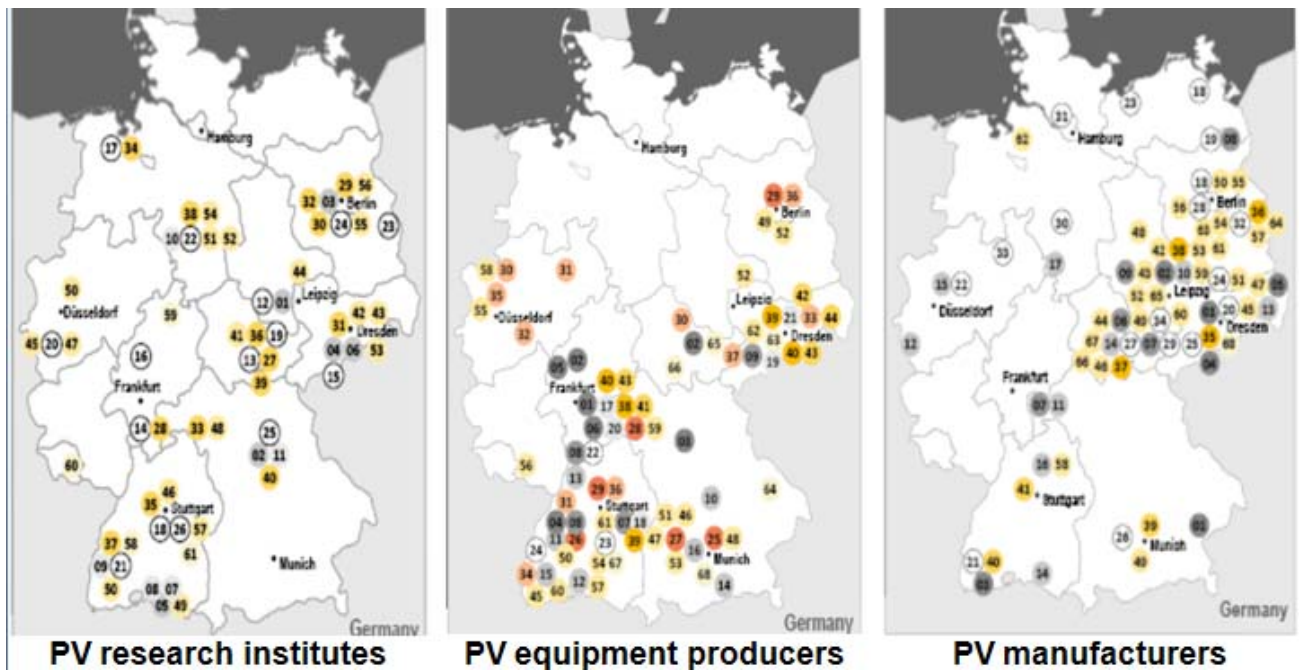
³⁵ Wissing (2008).

³⁶ GTAI (2009d).

amounted to approximately EUR 176 million in 2007, and between 2004 and 2007, the cluster registered over 250 patents.³⁷

Due to an extensive incentive program provided by the German government, the German PV cluster is concentrated in the former East-German states of Saxony, Thuringia, Saxony-Anhalt, and Berlin-Brandenburg. Over 90 percent of PV manufacturers in Germany are located in this region. While many PV equipment and machinery suppliers are spread further south into Bavaria, this is due to the well-established heavy machinery and equipment cluster located in that region. As for PV research institutes, there is a heavy concentration in both eastern Germany and Bavaria, so as to allow proximity to both manufacturers and equipment suppliers (Figure 6).

Figure 6. PV Cluster Geography



Source: GTAI (2009a-c).

While the solar irradiation levels in Germany are well below many other regions and countries of the world, the German PV cluster has developed successfully due to a number of key factors: (i)

³⁷ GTAI (2009d).

supportive government policies and incentives; (ii) the availability of a skilled labor force and high-quality infrastructure; (iii) significant investment in R&D; (iv) the presence of highly developed supporting industries; and (v) the depth and breadth of enabling industry associations.

The next three sections provide an overview of photovoltaic technology, the PV value chain and cluster map. Section 2.5 then elaborates analytically on each of the enabling factors that have been critical for growth of the cluster thus far. The final section brings to light challenges for the cluster going forward and provides recommendations for continued success.

2.2 Photovoltaic Technology³⁸

PV systems generate electricity from solar radiation. A PV system consists of PV modules that produce electricity and inverters that convert the generated direct current into alternating current.

Safe, durable, reliable, recyclable, and requiring little maintenance, PV modules used in PV systems have an estimated lifetime of 30 years. Customizable in size, the modules are weatherproof clusters of a large number of PV cells under a sheet of glass.

A PV cell is made of two layers of a semi-conductor material: positively charged and negatively charged. Electricity is generated when light shines on the semi-conductor. Therefore, a PV cell requires daylight, not direct sunlight. The most common semi-conductor material used in PV cells is silicon.

Crystalline silicon (about 90% of the market) and thin film technologies are the most widely commercialized PV technologies. Monocrystalline, polycrystalline, and ribbon sheets are the three main types of crystalline cells that are made from thin slices cut from a single crystal of silicon, a block of silicon crystals, or grown ribbons, respectively.

³⁸ Adapted from EPIA (2008) and EPIA and Greenpeace (2008).

The four types of thin film modules (amorphous silicon, cadmium telluride, copper indium diselenide, and multi-junction cells) differ in the active photosensitive material that is placed in very thin layers onto glass, stainless steel or plastic.

The efficiency measure for solar cells calculates what share of sunlight received is turned into electricity. Presently, the efficiency of crystalline silicon cells is 12-17%, while that of thin films is 5-13%.

Among other PV technologies that have been researched and commercialized are concentrated photovoltaics and flexible films. The former are designed to concentrate sunlight using a lens and saving on the semiconducting PV material. Their efficiency is a promising 20-30%. Flexible cells are based on thin film technology, but use flexible backing material, which has advantageous applications potential.

Small PV systems have been used in consumer electronics. Large PV systems can be used as grid-connected or stand-alone systems for domestic and industrial purposes. PV systems can be combined into hybrid systems that use electricity generated from other sources.

The future of PV technology lies in increasing the efficiency of PV cells and potentially greater integration of PV systems with applications such as PV integrated houses, buildings, construction materials, and fuel-efficient cars.

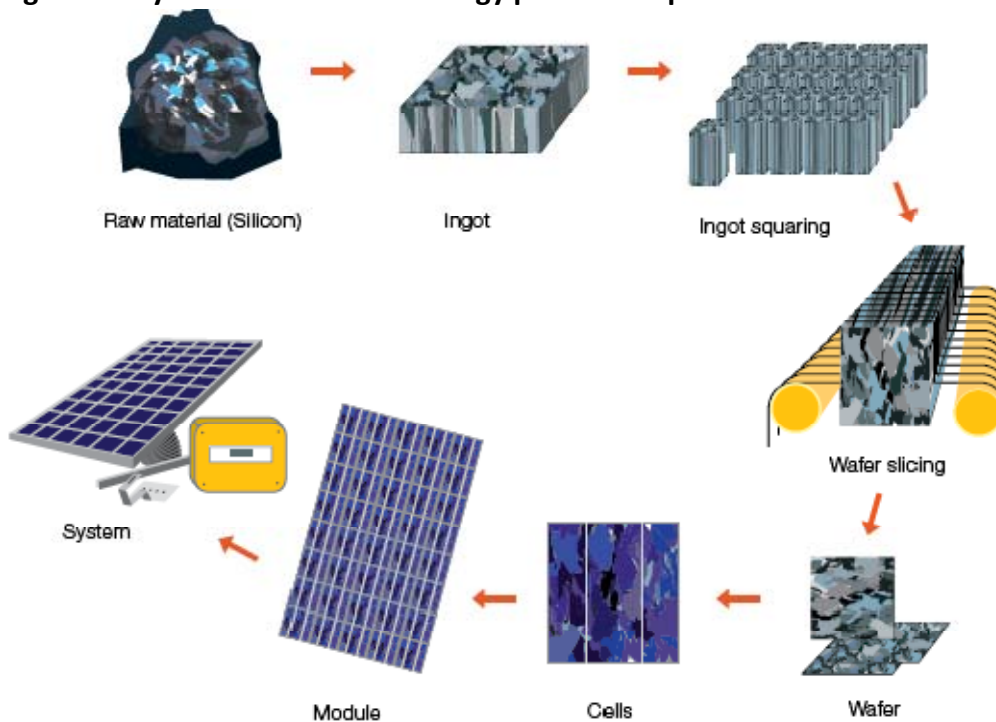
2.3 Photovoltaic Value Chain

The crystalline-based technology value chain has several distinct production stages (Figure 7):

1. Silicon feedstock production;
2. Silicon processing – silicon is processed into ingots and ingots are cut into squares;

3. Wafer production – wafers are sliced from the squared ingots;
4. Cell production – cells are produced from the wafers;
5. Module production – cells are put together in modules; and
6. System production – systems are produced from the modules and installed. It should be noted that production of inverters and other non-PV module components can be separated here as a sub-stage.

Figure 7. Crystalline-based technology production process



Source: EPIA (2008).

As silicon production and processing requires substantial investment and technical knowledge, the number of companies at this stage is relatively small. At the level of cell and module production, the number of producers is larger due to less intensive knowledge and investment requirements. At the very end of the value chain are installers that are usually small, local businesses.

Explosive growth of the global PV industry in recent years has led to shortages of silicon feedstock.

Electronic grade silicon had been historically produced solely for the semi-

conductor/microelectronics industry, but by 2007 over half of the worldwide electronic grade silicon was used by the PV industry. Solar grade silicon can be of lower quality than electronic grade silicon; therefore several companies, including new entrants, have chosen to produce it.

The non-PV module components account for 20-70% of the total PV system installation costs.³⁹ This part of the value chain, particularly inverters, has been growing substantially recently.

Clearly, the non-silicon thin film-based technology value chain differs in the upstream. There are no investment and knowledge intensive production stages related to silicon production. Instead, there are sourced photosensitive materials and glass, stainless steel and plastic. With lower production costs, thin film manufacturing has expanded rapidly – globally, film shipments have more than doubled between 2006 and 2007⁴⁰.

The German PV cluster houses companies specializing in all or parts of the PV value chain. For instance, Wacker-Chemie AG is one of the world's leading suppliers of silicon for the semiconductor and PV industries, Deutsche Solar AG and PV Silicon AG are the main suppliers of silicon ingots and wafers, and QCells has operations in virtually all parts of the value chain.⁴¹

2.4 Cluster Map

The map of the German PV cluster is depicted in Figure 8. At the center of the cluster are PV manufacturers, producers of PV equipment, and installers of PV systems – all players located along the entire value chain. PV equipment producers supply tools for all stages in the value chain and account for 15% of the cluster's revenue, or EUR 875 million in 2007.⁴²

³⁹ IEA (2006).

⁴⁰ Jager-Waldau (2008).

⁴¹ Ibid. and Wissing (2008).

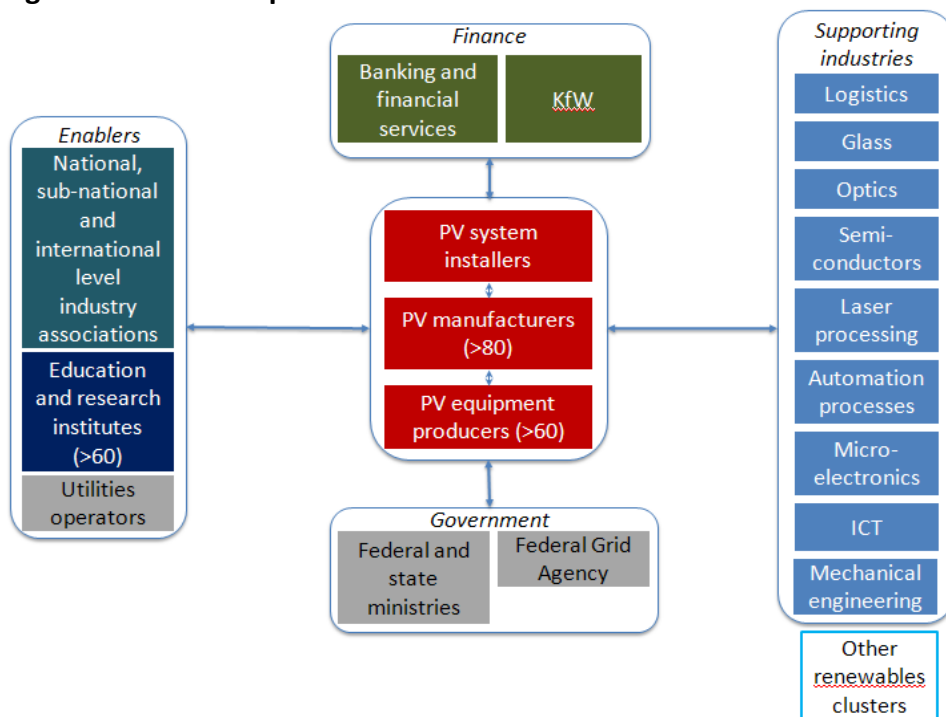
⁴² GTAI (2009a).

Finance is made available to the cluster through the banking system and funding programs from KfW (German Development Bank).

The existence of strong supporting industries has been instrumental for the quick development and upgrading of the cluster. The caliber of most supporting industries in Germany is such that they are usually leading industries in Europe and ranked among the top three or five globally.

Close cooperation with education and research institutions, industry associations, and utilities operators has been crucial for creating an enabling environment for the cluster. For instance, there are over 60 education and research institutes who train specialists and carry out R&D in clean technologies, including photovoltaics. Within the framework of the International Energy Agency's Photovoltaic Power Systems Program, Germany has collaborated with 18 OECD countries on joint photovoltaic R&D projects.

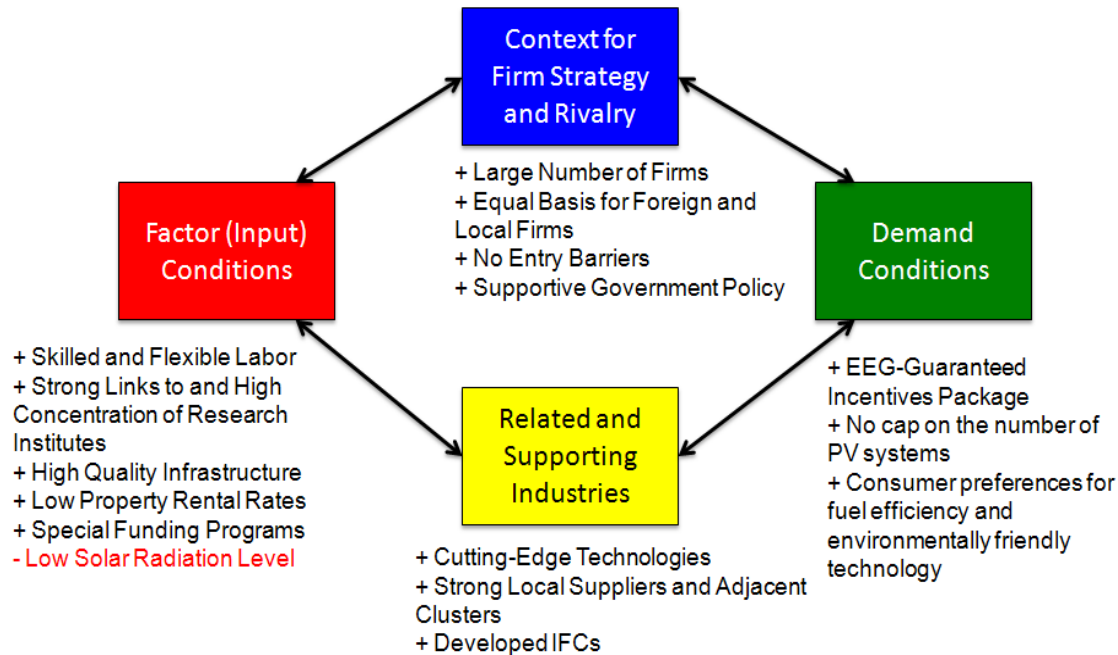
Figure 8. Cluster Map



Source: Authors' analysis.

Finally, the role of the government has been crucial in crafting and revising the Renewable Energy Act (EEG) in creating an expanding domestic PV market, limiting the administrative burden, and creating a non-discriminatory legal framework that provides for the same level playing field for domestic and foreign companies interested in participating in the photovoltaics business.

Figure 9. Cluster Diamond



Source: Authors' analysis.

The rapid development of the PV cluster in Germany is due to the very strong elements of its diamond (Figure 9). With high quality factor conditions, related and supporting industries, and a solid context for firm strategy and rivalry, the cluster has quickly reacted to improving demand conditions that have been created through the feed-in-tariffs and other investment guarantees under the EEG.

2.5 Key Success Factors for Development of the Cluster

(i) Government Policy and Incentives

The German government's policies to encourage solar PV technology and electricity production date back to the Electricity Feed-In Act of 1991 and 1000 Roofs Program of 1991-1995.⁴³ The Act and Program provided grid access to solar electricity producers for the first time as well as a refund payment of approximately EUR 0.085 per kWh, and tested the grid compatibility of PV systems. Between 1995 and 1999, the Government introduced further regional support programs and demo plants for PV producers, working towards the initiation of the 100,000 Roofs Program in 1999, which provided low-interest loans for 300 MWp of installed capacity.⁴⁴

In 2000, Germany passed the Renewable Energy Sources Act (EEG), requiring grid operators to pay a higher price to solar electricity producers (EUR 0.51 per kWh) than to providers of traditional fossil fuel electricity.⁴⁵ Then in 2004, the Government amended the EEG to introduce a feed-in tariff (FIT) system whereby solar electricity providers would be given a guaranteed price of between EUR 0.457-0.624 for a period of 20 years.⁴⁶ While the German government's pre-2000 policies helped spur interest and initial action in the solar PV sector, the introduction of the EEG in 2000 and subsequent amendment in 2004 were key milestones that helped the German PV cluster takeoff. In addition to the 20 year price guarantee provided under the 2004 amendment, an additional element of the feed-in policy was an annual reduction of 5 percent in the 20 year rate. This incentivized early entry into the PV sector as the rate PV electricity producers started at would be the rate they would keep for 20 years. Moreover, the FIT was provided to commercial PV providers as well as individual households that connected their solar panels to the grid. This encouraged

⁴³ Rafael Wiese, BSW 2007 (GTZ).

⁴⁴ Ibid.

⁴⁵ Ibid.

⁴⁶ Ibid.

widespread adoption of solar PV panels by German homes—by 2008, nearly 400,000 households in Germany had installed solar panels.⁴⁷

Apart from the FIT, the German Government also provided tax credits for commercial PV providers, including VAT exemption and a 20 year depreciation period for investments. The Government's policy framework aimed at making East Germany the hub for PV activity in Germany and therefore most incentives were geared towards firms setting up in the former East German states. For example, firms entering the East German cluster received investment incentives of up to 50 percent of capital expenditure, and the KfW provided low interest loans for private and commercial investors alike.⁴⁸ By 2008, the federal Government had provided about \$1.2 billion in subsidies to firms in the East German solar cluster. Notably, foreign firms and investors were welcomed and given incentives equivalent to German firms.⁴⁹ As a result, the East German PV cluster soon attracted some of the best international PV companies, which stood to gain from the myriad incentives, positive externalities and know-how afforded them by locating in East Germany.

Finally, in addition to the various investment incentives (such as low-interest loans and public guarantees) provided to PV companies, the Government also offered an extensive scheme of operational incentives, such as recruitment and training support, wage subsidies, and incentives for R&D.⁵⁰

(ii) Skilled Labor force and High-Quality Infrastructure

Another crucial enabling factor for the development of the German PV cluster was the plentiful supply of skilled labor as well as high-quality infrastructure. Over 25 percent of the German

⁴⁷ Caroline Bayley, "Germany's Sunny Revolution." Accessed at <http://news.bbc.co.uk/2/hi/business/7181866.stm>.

⁴⁸ GTAI (2009d).

⁴⁹ Ibid.

⁵⁰ Ibid.

workforce had university or vocational college education, and 50 percent of workers were classified as skilled craftsmen or technicians. Furthermore, the historical presence of the microchip and semiconductor industries in East Germany gave the region a highly-skilled and flexible labor force.⁵¹ Numerous universities developed solar technology and offered a range of graduate level courses with a strong focus on PV and renewable energies.⁵²

On the infrastructure front, the German Unity Transport Projects were launched in 1991 to close the infrastructure gap between East and West Germany. The projects involved a total investment of EUR 38.5 billion and included the construction of 9 railway ventures, 7 motorways, and 1 waterway.⁵³ Overall since 1990, over EUR 67 billion have been publicly invested to rebuild East German infrastructure that was subpar at the time of reunification. This huge investment in East German infrastructure led to a double advantage by 2007—not only was the quality of infrastructure completely modernized and top-rate, but the property and rental rates of the region were relatively low compared to West Germany and other cosmopolitan centers of Europe. Hence, setting up in the East German cluster was a win-win situation for companies in terms of costs as well as high-quality physical and technical infrastructure. Logistics centers were also abundant, with Berlin-Brandenburg alone boasting 5 freight traffic centers and nearly 100 large logistics companies.⁵⁴

Moreover, Germany had a 100 percent digitalized telecommunications network with 87,000 miles of fiber optics and an ISDN density five times higher than in the US or UK.⁵⁵ All in all, the availability

⁵¹ Caroline Bayley, “Germany’s Sunny Revolution.” Accessed at <http://news.bbc.co.uk/2/hi/business/7181866.stm>.

⁵² GTAI (2009d).

⁵³ German Federal Ministry of Transport, Building and Urban Affairs. Accessed at <http://www.bmvbs.de/en/Federal-Government-Commissione/-,2577/Infrastructure-for-unified-Ger.htm>.

⁵⁴ Accessed at http://www.zab-brandenburg.de/files/documents/SolarFolder_E_080820.pdf.

⁵⁵ GTAI (2009).

of highly-skilled and specialized workers, a good transportation system, and solid physical and technical infrastructure at relatively low costs made East Germany an ideal setting for the growth of the PV cluster.

(iii) Significant Investment in R&D

Under its High-Tech Cluster Strategy, the German federal government allocated significant resources towards energy and environmental technologies in 2006-2009. The presence of world-class research institutes together with a concerted public and private sector effort to invest in PV technology, has made Germany home to one of the richest PV R&D landscapes in the world. In 2007, the German PV industry invested EUR 175.8 million in R&D.⁵⁶ State-funded research has also been massive, given the federal government's commitment to invest EUR 6.5 billion in renewable energy research, technology and innovation in this legislative period.⁵⁷ Germany is especially focused on new PV technology areas such as organic photovoltaics, and in 2007, the German Ministry of Education and Research committed to invest EUR 360 million to support groundbreaking research on organic PV. As a result of this heavy emphasis on R&D, over 250 solar PV patents were registered in Germany between 2004 and 2007.⁵⁸

The close cooperation and collaboration between research institutes, universities and PV manufacturers and equipment suppliers has helped make the adoption of new PV technologies more cost effective and seamless. This has been a vital element in the German PV cluster's success to date.

⁵⁶ GTAI (2009d).

⁵⁷ Ibid.

⁵⁸ Ibid.

(iv) Highly Developed Supporting Industries

The presence of highly developed supporting industries, especially in semiconductors, optics, chemicals and glass, has also played a fundamental role in enabling the successful growth of the German PV cluster. The East German states where the PV cluster is concentrated were already home to the top semiconductor industry in Europe, as well as a vibrant optics industry with over 400 companies and 235,000 employees. In addition, Germany is the global leader in logistics, and ranks among the top 3 globally in information and communications technology (ICT). It is the European leader in the chemicals industry (among the top 4 globally), and has an extensive glass sector with 330 companies and 50,000 employees. Last but not least, Germany is a powerhouse in the machinery and equipment industry, harboring 6000 companies with 0.9 million employees, responsible for 28 percent of the world's mechanical engineering patents.⁵⁹

The depth and breadth of these supporting industries has provided the German PV cluster with a rich source of highly specialized workers, a ready supply of machinery and equipment inputs, and one of the best transport and ICT infrastructures in the world. The existence of these clusters together with the large number of PV firms located in such a concentrated area, has also led to many learning-by-doing externalities.

(v) Well Established Institutions for Collaboration

Industry associations have played an important role in coordinating the sharing and exchange of information. There are multiple organizations at the sub-national, national, European and international levels. For instance, the European Photovoltaic Industry Association (EPIA) unites members from the entire PV value chain and represents their interests at the national, international and global level. EPIA is the world's largest PV industry association representing about 80% of the

⁵⁹ GTAI (2009). Web-site: <http://www.gtai.com/homepage/industries>.

worldwide PV industry.⁶⁰ The German Energy Agency (DENA) is a child of the Federal Government and KfW, intended to serve as a competence center for energy efficiency with almost 6,000 sales offices.⁶¹ Finally, the Federal Solar Energy Association (BSW) unites over 650 members (producers, wholesalers, consultants, R&D institutes) and serves as a forum between solar businesses and the German government.

2.6 Challenges for the Cluster Going Forward

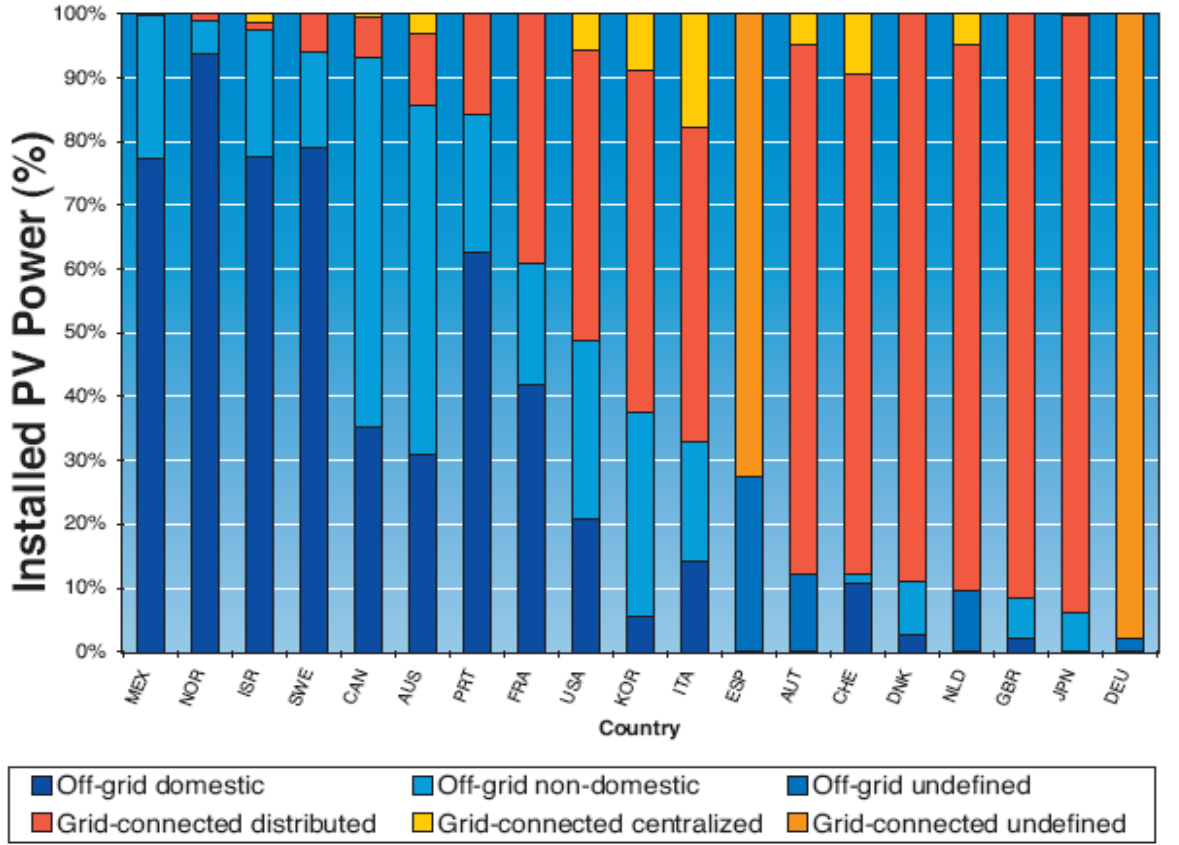
While Germany's PV cluster is slated to grow at a rate of 25-30 percent over the next decade,⁶² such growth will depend on the confluence of certain crucial elements: (i) demand conditions for solar PV within Germany and internationally; and (ii) the ability of the cluster to compete against rising PV markets in China, Spain and the USA. This section will expand on these elements that present potential challenges for the future success of the cluster. The final section will then provide recommendations to address these challenges and ensure future progress.

⁶⁰ EPIA (2009). Web-site: www.epia.org.

⁶¹ DENA (2009). Web-site: <http://www.dena.de/en/infos/about-dena>.

⁶² GTAI (2009b).

Figure 10. Installed PV Power by country, 2006



Source: IEA (2006).

(i) Demand Conditions in Germany and Abroad

Ensuring a growth rate of 25-30 percent for the German PV cluster in coming years will require robust demand for solar PV within Germany and abroad. Domestic demand conditions are promising. This is partly because of the German government’s goal to make the country a global leader in renewable energy and environmental sustainability, through incentive programs and such. But it is also due to the propensity of German consumers to purchase more fuel efficient cars and electronics, and be more environmentally conscious. Indeed, Germany’s commitment to environmental sustainability and renewable energy permeates German consumers and society on a social, cultural and ethical level, over and above government incentives.

In terms of international demand, the European Union's decision to increase the share of power obtained from renewable energy sources by 20 percent and to cut carbon emissions by 20 percent by 2020, should help keep demand for solar PV buoyant throughout Europe. In addition to its own market, Germany's location at the heart of Europe provides companies located in the East German cluster easy access to other growing PV markets in Spain, France and Italy. Furthermore, with the rapid growth in India, China and other developing countries, the strain on conventional power sources will only increase in coming years, making the move towards renewable energies inevitable. Not only will solar PV play an important role as a clean energy proxy for traditional sources of power, but it will also make it easier to provide electricity in rural and remote areas which are far removed from the grid. Germany's reputation for providing the highest quality goods makes the "Made in Germany" label on solar PV products attractive internationally.

Against this mostly positive backdrop, there are also some concerns regarding future demand conditions. In particular, once the German government tapers off incentives such as the attractive FIT provided to solar PV users at present, will this lead to a drop in PV production and demand? There are also concerns that the EU may introduce a system of trading renewable energy obligations (similar to the UK's system of Renewables Obligation Certificates) among member states, which could cause Germany's FIT mechanism to unravel.⁶³

(ii) Competition from Growing PV Markets in Asia, Spain, and the USA

While the German PV cluster has enjoyed a preeminent position in the global market so far, the cluster faces rising competition from growing PV markets in Asia (China, Taiwan, Korea), Europe and the USA. As more and more companies enter, the industry is becoming less consolidated. In fact, market share of the top 10 PV manufacturers fell from 80 percent in 2004 to 57 percent in 2007,

⁶³ Caroline Bayley, "Germany's Sunny Revolution." Accessed at <http://news.bbc.co.uk/2/hi/business/7181866.stm>.

and only two of the top ten companies are German.⁶⁴ Moreover, as China, Spain and other countries with much higher solar irradiance levels than Germany aggressively enter the PV sector, the German cluster will confront stiffer competition than ever before. The growth stories of China and Taiwan are particularly remarkable—China expanded PV production capacity from 3 MW in 2001 to 1070 MW in 2007.⁶⁵ As of 2007, 98 percent of Chinese and Taiwanese PV production was exported.⁶⁶

2.7 Recommendations for Continued Success of the Cluster

Given the challenges outlined above, we recommend the following policies to ensure continued success of the German PV cluster:

1. The German PV industry and Government must work in tandem to continue a high level of investment in PV R&D. Cutting edge technological innovations will enable Germany to build on its present market dominance in the PV sector. Not only will this enable the German cluster to compete against Chinese and Spanish counterparts, but will also expand the demand base for PV products (if technology leads to cost reductions).
2. Germany must coordinate with the EU to ensure that policies introduced on an EU-wide basis, such as trading certificates to meet renewable obligations, do not induce a sudden negative shock to the German PV cluster and policy framework.
3. Germany should remain completely open to foreign PV companies and continue to offer these companies the same incentives as German firms. In this way, even when PV markets such as Spain grow, the well-established German cluster will provide an attractive location for international companies looking to set up in Europe and access all markets there.

⁶⁴ Jager-Waldau (2008).

⁶⁵ Ibid.

⁶⁶ Ibid.

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