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Trade and Innovation: Report on the Chemicals Sector

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TRADE & INNOVATION: REPORT ON THE CHEMICALS SECTOR

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by Nobuo Kiriyama

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ABSTRACT

This study analyses linkages between trade and innovation in the chemicals sector, building on past work at the OECD on trade and innovation. The chemicals sector has a long history of innovation and is a large trading item. It covers very diverse sub-sectors. This paper analyses and compares different trade and innovation linkages in basic industrial chemicals, speciality and fine chemicals and consumer chemicals.

This sector has also been a subject of successive rounds of multilateral trade negotiations, and partly as a consequence tariff rates have been reduced over time. Nonetheless remaining tariffs are still non-negligible and constitute impediments to trade. Export restrictive measures on raw material inputs are also being highlighted on the trade negotiating agenda. Moreover, the chemicals sector is heavily regulated for health and environmental reasons and further legislative initiatives have been pursued, whose practical impact on innovation remains to be seen. Intellectual property has played a very important role in technology diffusion in this sector, and infringement of intellectual property continues to be a major problem.

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JEL Classifications: F13, F14, L65, O31

Keywords: Innovation, chemicals, multilateral trade negotiations, Chemicals Tariff Harmonization Agreement (CTHA), emerging economies, export restrictive measures, technical barriers to trade (TBT), environmental regulation, intellectual property, financial crisis

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EXECUTIVE SUMMARY

The chemicals industry has a long history of innovation as “the first science-based industry”. It occupies a large part of international trade and has continuously been the subject of multilateral trade negotiations. It is undergoing a major transformation with the rise of emerging economies and regulatory challenges.

World trade in the chemicals sector more than trebled between 1995 and 2008, particularly just after 2001. While high income countries represent the majority of world trade, low and middle income countries are steadily gaining importance, and South-South trade has recorded higher growth rates than other income group pairs. Emerging economies, such as China, are now among the major traders in this sector. Three quarters of world trade in the chemicals sector is in intermediate goods, and consumer chemicals and pharmaceuticals make up the rest. Tariffs have been reduced substantially over the same period, but their elimination remains as a subject in the current multilateral negotiations.

Different sub-segments of the industry*, i.e.* basic industrial chemicals, speciality and fine chemicals and consumer chemicals all have very diverse innovation characteristics. Basic industrial chemicals have limited opportunities to introduce new products and compete mainly on costs, whereas product innovation, responding to evolving customer needs transmitted through supply chains, is essential for speciality and fine chemicals. Process innovation is important for both of these sub-sectors to reduce costs, to improve sustainability (*e.g.* industrial biotechnology) or to pursue differentiation. For consumer chemicals introduction of new products and marketing approaches is the key. These different features of those sub-segments offer diverse channels through which trade affects innovation in the chemicals sector. First, the transfer of advanced technologies, both as embodied in capital goods as well as through technology licensing, has been the key to the emergence of the chemicals industry as a global industry, and the specialised engineering firms (SEFs) have played a unique role, especially in basic industrial chemicals. Second, product innovation in speciality and fine chemicals contributes to innovation in downstream sectors, and trade serves as an essential conduit to transmit such innovations across borders. Thirdly, as a consequence of the wider availability of technologies across the globe, technology leaders in developed countries are under increasing competitive pressure from new competitors, which induces further innovation. Fourth, foreign contacts through exports can give suppliers innovative ideas. The increasing strength of emerging markets is a challenge but it also offers opportunities for innovation. Finally, joint ventures and cross border M&A also function as channels of technology transfer.

The chemicals sector is heavily regulated both domestically and internationally, primarily for health, safety and environmental reasons. Under WTO rules, regulations may be considered legitimate if certain conditions are met. Many domestic regulations have been notified to the WTO according to the procedure provided in the TBT Agreement, and there have been over 1 600 notifications since 1995 in the chemicals sector. The impact of regulation on innovation can go either way; on one hand, regulation imposes extra cost and time burdens and diverts resources away from innovation, but on the other hand, environmental regulation can induce innovative activities and enhance energy efficiency. The actual impact of regulation on innovation is likely to be specific to the regulatory design and to the products and segments of the industry. The impact of recently introduced REACH legislation in the EU has been much discussed both in the legislative process within the EU and in international forums including the WTO. Beyond the EU, many major players in this sector have been pursuing regulatory initiatives to enhance data collection and to extend regulatory coverage to existing chemicals. Their practical impact remains to be seen, since they are still at an early stage of implementation or preparation. In relation to climate change issues, the chemicals sector is in a unique position as both a major sector in terms of energy use and CO2 emissions and as a major contributor to delivering solutions to combat climate change. Technological solutions to reduce reliance on fossil fuels by the chemicals sector are being sought, and chemical products are essential for greenhouse gas reduction in downstream industries. Further trade liberalisation can play an important role to accelerate the diffusion of products and technologies that contribute to climate change mitigation.

Intellectual property has particular importance in the chemicals sector because of the relative ease of producing chemicals as soon as the necessary technologies are known. Throughout the history of the chemicals industry, both patents and trade secrets have been used extensively to protect intellectual property, the choice depending on the nature of the technology and company strategy. Patents have been instrumental in facilitating technology transfer by licensing. The practice of co-patenting is generally correlated with trade flows, indicating the possibility that collaborative efforts in innovation foster trade flows, or that trade flows and collaborative innovation are mutually reinforcing. Infringement of intellectual property continues to be a major problem resulting in large losses to the intellectual property holders. Many multinational companies operating in China have taken various measures to protect their intellectual property, over and above efforts to strengthen intellectual property rights enforcement by the Chinese government. In addition, counterfeiting of chemical products (*e.g.* fertilisers and pesticides), which is often difficult to detect, can have serious consequences for the environment, health and safety.

During the recent financial crisis, the chemicals industry has been no exception in experiencing a decline in trade. Although it is considered that the initial fear of possible serious protectionist reactions has not materialised, chemicals and plastics are among the most affected industries by recently introduced trade-related measures. The recent developments underline the importance of the monitoring activities to ensure transparency and to seek an ambitious and balanced conclusion of the Doha Development Round.

I. Introduction

1. Background and the purpose of the study

1. The Trade Committee's work on Trade and Innovation in 2007-2008 (OECD, 2008a) highlighted various linkages between trade and innovation, drawing on case studies of various sectors in countries at different levels of development. Building on this, a first sectoral study has been undertaken focusing on the information and communication technology (ICT) sector.[1] This second sectoral study focuses on the chemicals sector.

2. There are several reasons for the choice of this sector. First, the chemicals sector (HS Chapters 28-39) occupies over 11% of the world trade, and it has been a specific subject of multilateral trade negotiations. Second, it has a long tradition of innovation as "the first science-based industry", and development and diffusion of technology has played an essential role in shaping the industry. Moreover, emerging economies and major regulatory issues relating particularly to health, safety and environment are changing the industry. Thus, there are unique issues to explore in the chemicals sector in relation to trade and innovation.

3. This paper is in five sections. The remainder of this section briefly introduces the concept of innovation and its contribution to trade, and discusses the scope of the chemicals sector covered in this paper. Section II reviews the evolution of trade and tariff profiles of the sector over the past ten years. Section III examines trade and innovation linkages focusing on three chemicals sub-sectors. Section IV discusses trade-related policy measures in the chemicals sector, and Section V concludes.

2. Trade and innovation: an overview

i) Innovation

4. OECD (2005, p.46) ("the Oslo Manual")[2] defines an innovation as the implementation of a new or significantly improved product (good or services), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations (. It is a continuous process that involves multiple aspects of firm activities.

5. Four types of innovations are distinguished: product innovations, process innovations, marketing innovations and organisational innovations. A product innovation is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. A process innovation is the implementation of a new or significantly improved production or delivery method. A marketing innovation is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. An organisational innovation is the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations. (Oslo Manual, pp.47-51) All innovations must contain a degree of novelty, which can be new to the firm, new to the market or new to the world (*ibid*, p.57).

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*This study is prepared with a contribution from Paul Wright, external consultant to this study.

[1] "Trade in ICT and its contribution to trade and innovation", [TAD/TC/WP(2009)11/PART1; TAD/TC/WP(2009)11/PART1/ANN and TAD/TC/WP(2009)11/PART2]

[2] The Oslo manual presents guidelines for collecting data on the general process of innovation, the implementation of innovations, the factors that influence innovation activities, and the outcomes of innovation. (Oslo Manual, p.15)

ii) Contribution of trade to innovation

6. Just as the concept of an innovation is multifaceted, the contribution of trade to innovation involves various channels.[3] As highlighted in OECD (2008a), technologies can move across borders through trade and investment as well as through licensing. Imports of capital goods are an important conduit for technology transfer as foreign-produced machinery often contains more technology than domestic machinery, especially in developing countries. Foreign direct investment also plays a key role in technology transfer and innovation. Multinational companies tend to innovate more than domestic companies, and there is also a growing recognition that internationalising production can be a way of gaining access to expertise and techniques that are complementary to a company's in-house assets. Second, imports and foreign direct investment both increase competition for domestic industries, which creates an incentive for firms to innovate in order to withstand competitive pressure. Empirical evidence suggests that, in high-technology industries, levels of innovation fall more rapidly when there is less competition. Third, globalisation of value chains, which itself is a type of innovation, may induce participating firms to improve efficiency in individual activities, to change their mix of activities, or to try to innovate by moving into another value chain (OECD (2008a), pp.14-42).

7. Openness to trade is, needless to say, not an instrument specifically designed to foster innovation, but it is one element of the framework conditions that affects broader aspects of the economy. As often emphasised, openness to trade (or more generally the right framework condition) on its own does not ensure innovation (or other desirable economic outcomes),[4] and given the increasingly central role of innovation in delivering a wide range of economic and social objectives, a "whole-of-government" approach to policies for innovation is needed (OECD, 2010a). Nevertheless, as summarised above, openness to trade is an essential condition that facilitates, or enables, diffusion of technologies for a broader range of firms across the border to take up and innovate, and gives the right incentive for firms to innovate. This study examines how these channels work in the chemicals sector.

3. The scope of the chemicals sector and the nature of innovation

8. The chemicals sector comprises a series of diverse and inter-related sub-sectors covering a wide range of technologies and processes. The output of the industry is mostly used by other companies as inputs, but it also covers finished goods used by consumers. Chemical inputs are essential to many different industries, not only to the chemical industry itself, or to other manufacturing industries such as automotives, electronics and textiles, but also to agriculture and services.[5] In order to properly take into account the diversity of this sector, it is useful to introduce certain sub-groupings within the industry. For this purpose, this paper makes reference to "basic industrial chemicals", "speciality and fine chemicals", "consumer chemicals" and "pharmaceuticals" as sub-sectors.[6] Basic industrial chemicals cover inorganic and organic chemicals as well as petrochemicals and fertilisers, which are typically produced on a large scale. Speciality and fine chemicals are medium to high value products and produced on a smaller scale.

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[3] *See* OECD (2008a), Tables 1 and 2.

[4] Speeches by Pascal Lamy, Director General of the WTO, "Facts and Fictions in International Trade Economics" (12 April 2010, at the Paris School of Economics), "Reconciling America with an open trading system" (24 April 2009, in Washington, D.C.),

[5] CEFIC (2009), p.8; ICCA (2005), p.4. In one estimate, 96% of manufactured goods have a direct nexus to the chemicals sector (Durbin, 2009).

[6] HLG (2009) uses largely similar divisions: petrochemicals, basic inorganics and polymers; speciality chemicals; and consumer chemicals (pp.6-7). Thomson Reuters Business Classification divides Chemicals (under Basic Materials) into Commodity Chemicals, Agricultural Chemicals, Specialty Chemicals and Diversified Chemicals. *See also* Swift (1999), p.33; OECD (2001), p.10.

They include paints and pigments, industrial gasses, sealants and adhesives and catalysts, but some organic chemicals and plastics can also belong to this category. Consumer chemicals are in general formulated products such as soap, detergents and cosmetics. Together (including pharmaceuticals) they nearly correspond to the coverage of the Chemicals Tariff Harmonization Agreement (CTHA) in the Uruguay Round.

9. It should be noted that the boundaries of the sub-sectors are fluid and not always clear-cut, and statistics are not necessarily suited to capturing these different segments (Swift (1999), p.33). Adding to this, "chemicals" in different studies may actually refer to a varying scope of products; in particular, pharmaceuticals are often, but not always, treated as a separate industry, and consumer chemicals are sometimes excluded, either explicitly or implicitly.[7] This paper does not specifically focus on pharmaceuticals in its analysis of trade and innovation linkage in Sections III and IV, since it is quite distinct in terms of both trade and innovation performances (*see* Section II and Section III.1) and may well merit a specific study in its own right.[8]

II. Trade and tariffs in the chemicals sector

1. Evolution of trade[9]

10. World trade in the chemicals sector (defined as HS Chapters 28 to 39 in this Section;[10] *see* Table 1 for descriptions) more than trebled between 1995 and 2008 (Figure 1). While high income countries (HICs) have the largest share in world trade, low and middle income countries (LMICs) have been steadily gaining market share during this period. Taking a closer look at the differences by sub-sector and by income group provides further insight. First, whereas the annual growth rates in chemicals (excluding pharmaceuticals) have been similar to those in total merchandise trade, the growth rates in pharmaceuticals (Chapter 30) have been quite different.[11] The growth in pharmaceuticals was notably higher in HICs, compared with other HS Chapters. In contrast, the growth in fertilisers (Chapter 31) was particularly higher in LMICs (Figure 2). Second, in terms of levels of trade, there is a high concentration on organic chemicals and plastics (HS Chapters 29 and 39; generally considered basic industrial chemicals), followed by pharmaceuticals, which together account for 70% of trade in chemicals (Figure 3). The composition of trade is different between the HICs and the LMICs, with trade in pharmaceuticals strongly concentrated in the former, with inorganic chemicals and fertilisers more concentrated in the latter group.

11. Trade in chemicals between LMICs (South-South trade) has been low but steadily increasing from 5% in 1995 to close to 10% in 2008; in turn, the share of trade between HICs, while still dominant, has gradually declined from over 70% to 60% during the same period (Figure 4). Trade between LMICs has recorded faster overall growth in the chemicals than other income group pairs during the period, with the notable exception of pharmaceuticals. Plastics and organic chemicals together account for 40-50% of increased growth after 2001 across different income group pairs, while pharmaceuticals was by far the

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[7] *See e.g.* Swift (1999), p.33 (explicitly excludes consumer products from the discussion); Thomson Reuters Business Classification (establishes Personal & Household Products separate from chemicals).

[8] *See e.g.* OECD (2006).

[9] *See* Appendix 1 for technical details of the data.

[10] This coverage is in reference to the CTHA. However, it contains some headings covered by the Agreement on Agriculture thus not covered by the CTHA or current proposal on liberalisation of tariffs in chemicals sector in the Doha round.

[11] WTO (2005a), pp.17-18 investigates into the possible reasons for sharp growth of trade in pharmaceutical sector, and it attributes to strong demand and industrial restructuring as a major factor.

largest contributor to trade between HICs. Pharmaceuticals are also the largest trading item between HICs, while trade in fertilisers is mainly between LMICs. The largest trade item between the two income groups is plastics, followed by organic chemicals.

12. The largest traders are the EU (external trade as a group), Germany and the United States, followed by Belgium, France and China (Figure 5). Here again, significant acceleration of growth in the 2000s can be seen across countries. The composition of exports varies considerably between countries; many OECD countries have high shares in pharmaceuticals (except Japan and Korea) alongside India, while many East Asian economies (Korea; Chinese Taipei and Hong Kong, China) are more specialised in plastics.

13. Classifying in terms of end use, intermediate goods (industry supplies and others) make up for three-quarters of trade (Figure 6). This concentration in intermediate goods is even higher for the LMICs. The most noticeable change between 2000 and 2007 was the increase in the share of pharmaceuticals, especially in the HICs. Despite a significant increase in the absolute value of trade in other types of chemicals, the shares of intermediate goods (except exports from the LMICs) and consumer chemicals (other than pharmaceuticals; *e.g.* perfume, cosmetics, soap and plastic articles) declined during this period.

Table 1. HS chapters and descriptions[12]

28. Inorganic chemicals; organic or inorganic compounds of precious metals, of rare-earth metals, of radioactive elements or of isotopes.
29. Organic chemicals.
30. Pharmaceutical products.
31. Fertilisers.
32. Tanning or dyeing extracts; tannins and their derivatives; dyes, pigments and other colouring matter; paints and varnishes; putty and other mastics; inks.
33. Essential oils and resinoids; perfumery, cosmetic or toilet preparations.
34. Soap, organic surface-active agents, washing preparations, lubricating preparations, artificial waxes, prepared waxes, polishing or scouring preparations, candles and similar articles, modelling pastes, "dental waxes" and dental preparations with a basis of plaster.
35. Albuminoidal substances; modified starches; glues; enzymes.
36. Explosives; pyrotechnic products; matches; pyrophoric alloys; certain combustible preparations.
37. Photographic or cinematographic goods.
38. Miscellaneous chemical products.
39. Plastics and articles thereof.

2. Tariff profiles in the chemicals sector

14. Tariff rates have been coming down since the conclusion of the Uruguay Round (Figure 7(a)). The average MFN applied tariffs on chemicals by the original CTHA (Chemicals Tariff Harmonization Agreement) participants are about 2%, and non-participants have also reduced their rates from over 10% to single digits. This reduction is not necessarily due to the implementation of commitments under the WTO (Uruguay Round commitment or accession commitment) but includes unilateral tariff reduction, especially by non-CTHA participants. Therefore, despite a certain degree of convergence of tariff rates across

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[12] Although this structure does not precisely correspond to the sub-groupings used in this paper, CEFIC (2009), p.18, uses the following categorisation: “basic inorganic” (28, 31), “petrochemicals (29), polymers (39, 54, 55), “pharmaceuticals” (30), “specialty chemicals” (32, 35, 38) and “consumer chemicals” (33, 34).

countries, levels of WTO bound rates in non-participants are considerably higher than other groups (Figure 7(b)). Tariff reduction has taken place across different HS Chapters, but tariff rates are generally lower for basic chemicals (Chapters 28-29) and higher for more highly processed chemical products (Chapters 33-36) (Figure 8).[13] This reflects the structure of CTHA, but it is also the case with non-participants.

15. An estimate of the amount of duties collected on imports shows that the largest amount is collected by non-CTHA participants, despite tariff reductions in recent years (Table 2). It also shows that the duty collection by original CTHA participants and new WTO members also remains substantial, due to large import value as well as to the remaining tariffs. It is worth noting, however, that whereas tariffs for CTHA participants are bound at levels close to applied tariffs, tariffs for non-CTHA participants are bound at much higher levels and can be raised by their policy decisions.

16. A breakdown into HS Chapters shows that plastics represent the largest share of duty collection, followed by organic chemicals. The share of pharmaceuticals is significantly higher in non-CTHA countries (Table 2).

Table 2. Estimate of chemicals duty share (%) by HS chapter (2008) [14]

	By Group	**By HS Chapters**				
		Ch. 29	Ch.30	Ch. 38	Ch. 39	Others
CTHA	30	37	2	7	31	22
Non-CTHA	37	11	16	7	35	30
New WTO	31	24	2	8	44	22
Other OECD	2	9	1	5	55	30
Total	100	23	7	7	37	25

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[13] Higher average tariff rates for Chapter 35 (in particular in CTHA group) reflect the existence of agricultural products in the Chapter, which are not covered by the CTHA. Remaining duties in Chapter 30 reflect transposition in HS classifications.

[14] The amount of duty is estimated as (weighted average effective applied tariffs for an HS Chapter in a country)x(corresponding import value). Where data are missing for 2008, data from closest available years are used. The amount of duties actually collected at the customs is not identical to this calculation because of application of rules of origin, special incentive schemes and other factors that are not reflected in duty rates in the database. “Non-CTHA” includes non-WTO members (Russia and Belarus). “Other OECD” consists of Australia, Iceland, New Zealand and Turkey.

Box 1. The Chemicals Sector and Multilateral Trade Negotiations

The chemical sector has been featured during successive rounds of multilateral trade negotiations. During the Dillon Round (1960-61), European countries made their tariff reductions on organic chemicals conditional on the abolition of the American Selling Price system of valuation for customs purposes (ASP) by the United States, but no agreement was reached. In the Kennedy Round (1964-67), European countries made their offers on the entire chemicals sector (Chapters 28 to 39) conditional on the abolition of the ASP. Informal groups were established in five sectors, including chemicals, to deal with the sector specific problems (GATT, 1975a). The negotiations resulted in a formal plurilateral "agreement" on chemicals[15] (WTO (2005b), para. 14). During the Tokyo Round (1973-79), the Negotiating Group "Sectoral Approach" was established and worked on various sectors including chemicals,[16] but it produced no agreement on the sector on a plurilateral basis.

The Uruguay Round (1986-94) produced several successful plurilateral sectoral negotiations, including the chemicals tariff harmonisation agreement (CTHA) and the tariff elimination ("zero-for-zero" agreement) in pharmaceuticals (WTO (2005b), para.27). Initially, contracting parties interested in particular sectors indicated those sectors in their tariff reduction proposals in 1990-91, which was followed by negotiations (Stewart *et al.* (1995), pp.414-43). In July 1993, the United States, European Communities, Canada and Japan announced an agreement on necessary elements for a final agreement, which included a common list of sectors for tariff and non-tariff measure elimination (*e.g.* pharmaceuticals) and tariff harmonisation in chemical products (GATT, 1993). Under the CTHA it was agreed to harmonise and bind the tariff rates at 6.5% (HS Chapters 31-39 and 2916-2942), 5.5% (HS28 and 2903-14) and 0% (HS2901-2902 and HS30) with 5, 10 or 15 years of staging depending on the base tariff levels (WTO, 2006; WTO, 2005), except for products covered by the Agreement on Agriculture. This agreement initially had the following participants: Canada, Czech Republic, European Communities (12), Japan, Korea, Norway, Singapore, Slovak Republic, Switzerland and the United States (Hoda, 2002, p.30). Many more countries have since subscribed to the same or similar commitments in particular the recently acceded members to the WTO as a part of their accession commitments.

On pharmaceuticals, it was agreed to eliminate tariffs on items in HS Chapter 30; items in HS headings 2936, 2937, 2939, and 2941, with the exception of dihydrostreptomycin and salts, esters, and hydrates thereof; and other items including active ingredients which bear an international non-proprietary name (INN) from the World Health Organization, and certain additional products used for the production and manufacture of finished pharmaceuticals. The participants were Australia, Canada, Czech Republic, European Communities (12), Iceland, Japan, New Zealand, Norway, Singapore, Slovak Republic, Switzerland and the United States (GATT, 1994). There have been three rounds of reviews of the product coverage, which resulted in inclusion of additional products (WTO 1996, 1998, 2007).

In the current Doha Development Agenda negotiations (2001-), proposals have been tabled for sectoral tariff elimination in the chemicals sector (Chapters 28-39) and for open access to enhanced healthcare (Chapter 30 as well as some items from other Chapters including Chapters 28, 29, 87 and 90) (WTO, 2008).[17]

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[15] Agreement relating principally to Chemicals, Supplementary to the Geneva (1967) Protocol (GATT, L/2819, 17 July 1967).

[16] For example, in the process of the work in the Group "Sectoral Approach", the United States proposed further studies on the chemicals, electronics, and heavy electrical equipment sectors (GATT, 1975b).

[17] International Council of Chemical Associations (ICCA) has expressed its support for the initiative (ICCA, 2001, 2005).

III. Innovation in the chemicals sector and the role of trade

1. Innovation activities in the chemicals sector

i) A short history of innovation in the chemicals sector

17. The chemical industry[18] has a long history of innovation. It started in the first half of the nineteenth century as mostly processing of inorganic chemical compounds taken from the earth into more useful products such as lime and soda ashes. The chemical industry was made "the first science-based industry" with the launch of organic chemistry in 1856 in Britain, in which inputs such as coal and oil are transformed into benzene, ethylene and so on. In particular the production of dyestuffs became the engine of growth until WWI, especially in Germany. The advent of polymer chemistry in Germany in the 1920s opened the door for the petrochemicals industry, developed initially in the United States, contributing to large scale production of a diverse range of polymer products such as synthetic fibres, plastics, adhesives and paints. A third stage of technological changes is taking place based on the advent of biosciences.

18. Basic production technologies were diffused geographically over the twentieth century, initially among the United States, Europe and Japan and subsequently in Asia and the Middle East. Competitive pressure has pushed the industry to restructure, especially in developed countries, moving away from a conglomerate structure with physically integrated assets and moving to the areas of core competence and product differentiation, often through divestment, mergers and acquisitions (M&As). Re-organisations of existing companies as well as the emergence of new entrants (SABIC, Sinopec) have made the top 10 chemical companies list considerably different over the past 10 years (Table 3).[19] It is predicted that by 2015 there will be only four top-ten producers in developed countries (KPMG International (2010a), p.9).

19. The recent financial crisis has hit the sector in varying degrees depending on the fortunes of the downstream users, with the chemicals for automotive and construction industry being hit the hardest, and those for pharmaceuticals, food and personal care being hit the least. Nevertheless, the economic downturn has generally reinforced the need for further innovation in accordance with the key competitive advantage of the business segment. In doing so, wider range of collaboration across the boundary of the firms in various activities, including R&D, distribution and marketing, is being called for. In a larger context, the financial crisis is considered to accelerate the shift in the centre of gravity of the industry to the emerging economies, as companies with cost advantages and better financial positions in the aftermath of the financial crisis expand their businesses.[20]

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[18] This and the following paragraphs draws on Landau and Arora (1999), Swift (1999) and Cesaroni *et al.* (2004), pp.125-131.

[19] *See* Engman *et al.* (2006), pp.101-134 for a comparative study of structural adjustment focusing on the petrochemicals sector in major producing countries.

[20] *See* remainder of this section for more discussions.

Table 3. Top 10 chemical companies, 2008/1998 (sales in USD billions)

2008 (1998)	2008	Sales	1998 (2008)	1998	Sales
1 (2)	BASF	87.7	1 (12)	Bayer	32.9
2 (13)	Exxon Mobil	58.1	2 (1)	BASF	32.4
3 (5)	Dow Chemical	57.5	3 (-)	Hoechst	26.2
4 (-)	LyondellBasell Industries	50.7	4 (9)	DuPont	24.7
5 (12)	Shell	49.1	5 (3)	Dow Chemical	18.4
6 (-)	INEOS	41.0	6 (-)	Rhone-Poulenc	15.5
7 (33)	SABIC	40.2	7 (-)	ICI	15.4
8 (-)	Sinopec	35.4	8 (11)	Elf Group	14.8
9 (4)	DuPont	30.5	9 (14)	Akzo Nobel	14.6
10 (10)	Mitsubishi Chemical	29.9	10 (10)	Mitsubishi Chemical	12.9

Source: ICIS Chemical Business (2009) p.18, ICIS (2009).

ii) Diversity of innovation in the chemicals sector

20. Various measures of innovation indicate that the chemical industry is among the most innovative industries. A study on innovation performance ranking of European industries put "chemicals and chemical products" in fourth place, after "electrical and optical equipment", "ICT" and "Computer services and related activities", and just above "motor vehicles, trailers and semi-trailers" (Hollanders and Arundel (2005), p.14). It is similarly the case in the majority of the 15 European countries surveyed. The proportion of innovative firms is higher in chemicals than in manufacturing industry as a whole, both in terms of product and process innovation, and of organisational and marketing innovation. And this is consistently observed across different countries in this survey.[21]

21. However, aggregated numbers for the "chemicals sector" mask the substantial diversity of its sub-sectors. The difference is particularly visible in R&D intensity for pharmaceuticals and the rest of the chemicals sector (Figure 9(a)), and as a result pharmaceuticals are often presented separately from the rest of the chemicals.[22] This gap has widened in many countries over the past 10 years, as the R&D intensity in pharmaceuticals went up while it dipped in the rest of the chemicals (Figure 9(b)).

22. Neither should the diversity among the rest of the chemicals sector be overlooked. Available data up to the 1990s show that R&D intensity tends to be higher in speciality and consumer chemicals than in basic industrial chemicals (Fleischer *et al.* (2000), p.85; Figure 10(a)). Moreover, R&D intensities in different sub-sectors have also been diverging over time. Deloitte (2009, p.9) reports that while the R&D intensity (R&D/revenues) for speciality chemicals remained in the range of 3.0-3.5% during 1998-2008, it has declined from over 2% to 0.5% for commodity chemicals during the same period.

23. The purpose of R&D spending is also very different in different sub-sectors. A study on European chemical firms in 1990s shows that only 30% of basic chemicals firms spend more than 75% on product innovation, while more than 60% of agrochemicals, paints and varnishes companies do so

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[21] *See also* Aschhoff *et al.* (2008), p.11 (innovation survey results in Germany) and Mercer (2004) (in UK).

[22] *See e.g.* European Commission (2008), p.44. Given the different nature of pharmaceuticals, innovation in pharmaceuticals is not the primary focus of this study. Hollanders and Arundel (2005) also acknowledges that one factor behind the high ranking of "chemicals and chemical products" sector is presence of pharmaceuticals (p.30). However, data availability at disaggregate level often limits the possibility of separate analysis (*see cf.* Patel (2008), p.2).

(Albach *et al*. (1996), p.44-47). On the other hand, a larger share of companies in basic chemicals spends heavily on process innovation than those in other sub-sectors (Figure 10(b)).

24. The contribution of new products to sales further illustrates such diversity. A survey of American chemical companies shows that, whereas new products contribute to 10% of the sales of basic chemicals, they contribute to 23% for speciality and fine chemicals (ACC, 2009).

25. Table 4 illustrates such diversity of focus in innovation in different sub-sectors.[23] Among the four major types of innovation, the emphasis has generally shifted over time from product innovation to process innovation in this industry (Hutcheson *et al.* (1996), p.21), but this shift best applies to basic industrial chemicals (Hutcheson *et al.* 1995). With limited scope for product innovation, their focus is on process innovation and organisational innovation to improve productivity and cost advantage. In contrast, product innovation is of primary importance in speciality and fine chemicals, where there is still scope for new products and molecules that can be protected by patents and as trade secrets, and as a result price competition is less intense compared with that facing trade in basic industrial chemicals. Process innovation also plays an important role. In consumer chemicals, renowned for marketing innovation, consumers' preference drives product innovation. The remainder of this section will examine the underlying industry characteristics of these differences.

Table 4. Different foci of innovation in sub-sectors of chemicals industry

	Basic Industrial	Speciality and Fine	Consumer
Product Innovation		x	x
Process Innovation	x	x	
Marketing Innovation			x
Organisational Innovation	x		

iii) Underlying Innovation Strategies in Different Segments

26. To better understand the different foci of innovation, it is useful to refer to the framework for structural analysis of industries proposed by Porter (1980, 1985) before turning to sub-sectors.[24] According to the framework, five basic competitive forces – entry, threat of substitution, bargaining power of buyers, bargaining power of suppliers, and rivalry among current competitors – define the state of competition in an industry (Porter (1980), p.3-4); in coping with these competitive forces, firms have two sources of competitive advantage, cost leadership and differentiation (*ibid*, pp.34-40).

27. In the case of basic industrial chemicals, major entry barriers are the initial capital requirements and the costs associated with technology, supply of raw materials and location. The source of competitive advantage is the cost of production because product differentiation is not likely to take place. For speciality and fine chemicals, major entry barriers are product differentiation (*e.g.* product differences and customer relations) and differentiation is the major source of competitive advantage. Consumer chemicals are closer to speciality and fine chemicals than basic industrial chemicals, but product differentiation (*e.g.* brand loyalty) is a particular entry barrier, and therefore differentiation is typically the key source of competitive advantage.

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[23] Burgess *et al.* (2002), Figure 2 gives broadly similar illustration. However, this table is only indicative and does not suggest that individual firms may not undertake other types of innovation.

[24] The adaptation of Porter framework to the chemicals industry is drawn on Cesaroni *et al.* (2004), p.124; Frohwein and Hansjürgens (2004), pp.26-27. Government can influence many aspects of industry structure (Porter (1980), pp.28-29).

28. In another related but different framework, Treacy and Wiersema (1993) set out three value disciplines, operational excellence, customer intimacy and product leadership, as paths for market leadership. Operational excellence means to provide customers with reliable products or services at competitive prices and delivered with minimal inconvenience; customer intimacy means segmenting and targeting markets and tailoring offerings to match the demands of those niches, thereby establishing customer loyalty; and product leadership means offering customers leading-edge products and services that enhance the customer's use of the product, rendering the competitors' product obsolete. Operational excellence is closely linked to cost leadership (as in basic industrial chemicals), while customer intimacy and product leadership can be seen as two possible means for product differentiation (as in speciality and fine chemicals and consumer chemicals), which are also reflected in the different foci of innovation in different sub-sectors.

29. This is inevitably a broad generalisation subject to exceptions and evolution over time. In particular, the question of where to find the source of competitive advantage, or the key value disciplines, is further accentuated in the economic conditions after the financial crisis (Hodges, 2009).

2. Subsectors

i) Basic industrial chemicals

(a) Industry characteristics

30. Basic industrial chemicals are essentially commoditised products with established specifications, including organic chemicals (mainly derived from petrochemicals) and inorganic chemicals as well as polymers such as polyethylene and polypropylene. They are produced and sold in large volumes and occupy a major part of sales value in the chemicals industry.[25] Opportunities to introduce fundamentally new products are limited, although variations of existing products can be introduced in response to market needs, thus process technology tends to be more important than product innovation. Production plant location is mainly driven by production cost and the supply of raw materials and markets.

31. Manufacturing takes place at large dedicated and capital intensive plants using highly specialised processes. Process choices need to be made based on the current and projected costs (*e.g.* future energy and regulatory costs) at the time of plant design, since fundamental process changes *ex post* are very expensive due to their high capital intensity and degree of specialisation, even if incremental investments are often made in order to keep up with developments in process technology as well as to ensure compliance with new regulatory requirements, to improve health and safety conditions at the plant, to eliminate impurities and to re-balance product composition.

32. High initial capital requirements are a major barrier to entry. On the other hand, the availability of key process technologies through licensing has substantially reduced the entry barrier. Available data in the 1980s (Figure 11(a)) show the prevalence of licensing in sectors with large scale production facilities and relatively homogeneous products (*e.g.* petrochemicals). In particular, licensing from specialised engineering firms ("SEFs") has been particularly important for smaller chemical companies or "non"-chemical companies, which do not have sufficient in-house technological capabilities (Figure 11(b)). SEFs originated in the United States in 1950s and further spread to Germany and other developed countries,[26] and they have played an essential role as technology suppliers in processes and plant design to

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[25] Sales share of European chemical industry (2007) by sub-sectors: "base chemicals" (45%), "specialty chemicals" (17%), "consumer chemicals "11%) and "pharmaceuticals" (27%). (CEFIC (2009))

[26] The world market share of SEFs licenses (in total number of plants) in 1980-90 was: US (15.1%), West Germany (8.8%), UK (2.4%), Italy (1.6%), France and Japan (0.7% each). (Cesaroni *et al.* (2004), p.146.)

Europe and Japan through to developing countries. Figure 13(b) also shows that not only SEFs but also chemical companies have been active as technology suppliers.[27] The availability of technology from these technology suppliers has been critical to the global emergence of chemical industry we see today.

Box 2. The Functions of Chemical Engineering Companies

The business of chemical engineering companies usually involve one or some of the following four categories:

(i) Licensing of Process Technologies: Process technologies optimised for specific products are developed and licensed to users, especially in basic industrial chemicals.

(ii) Licensing of equipment designs: Equipment optimised for a particular chemical process are designed and licensed to users, especially in basic industrial chemicals. The optimisation involves appropriate control of kinetics, thermodynamics and mass transfer processes and designed by using computer modelling.

(iii) Supply of manufacturing equipment: This may involve equipment not dedicated to a particular chemical process but can be used in different processes (especially in speciality and fine chemicals).

(iv) Supply of catalysts: Catalysts designed for a particular process are developed and supplied to users. Catalysts are an essential part of many chemical processes and have a finite useful life. Suppliers provide replacements and can improve them through R&D.

(b) Technology transfer and entry of emerging economies

33. The trade and innovation linkage in basic industrial chemicals has been making a serious impact on the chemicals industry. The large scale transfer of technology from developed countries to emerging economies through SEFs and chemical companies as well as through joint ventures and M&As have helped emerging country players to innovate and enter into the global market; this has in turn created competitive pressure on developed country players to innovate further.

34. Many emerging economies have been actively promoting the chemical industry to exploit their cost advantage and proximity to raw materials (oil and coal) and to growing domestic and neighbouring markets.[28] For example, the Indian government has taken steps to improve the competitiveness of the chemical industry by abolishing industrial licensing to most of the chemical subsectors, approving FDIs up to 100 percent, reducing the list of reserved chemicals for the small-scale sector, and setting up integrated Petroleum, Chemicals and Petrochemicals Investment Regions (PCPIR) (Prahalathan (2007), p.50; KPMG International (2009b), pp.3-4). In China, petrochemicals is one of the industries in Plans for Promoting the 10 Leading Industries, announced in January-February 2009, for which large projects are to be supported in a prioritised manner, with a target to increase the industry's value added to 1.75 trillion Yuan by 2011 (Kwan, 2009). Chemical parks of various scales have been developed, large ones encompassing entire

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[27] At a first glance, active technology licensing by chemical companies looks puzzling, since this appears to be a sure way to increase the number of competitors. One explanation is that it was prompted by licensing by SEFs, since even if chemical producers do not license their technologies, SEFs will do so anyway (and they are under no pressure of potential competition), and it is better for chemical producers to license their technology and make some additional profit out of licensing. An alternative explanation is that such licensing by chemical companies may also be a part of their strategies, such as to impose a technology standard or to provide customers with secondary suppliers using the same technology (Cesaroni *et al.* (2004), p.148-49). *See also* Arora (1997), pp. 397-99; Arora and Fosfuri (1998), pp.10-14.

[28] *See cf.* KPMG International (2010a), pp.8 and 10.

value chains designed for global players and medium-sized ones developed for domestic investors (KPMG International (2009c), p.13; Table 5 below).

35. Large-scale investment plans in China and the Middle East announced around 2005 are now being made operational. It is estimated that new capacity in 2010 in the basic commodities category will comprise almost 8% of the existing global capacity, and nearly 80% of the new capacity in 2009-13 will be installed in China and Middle East (Deloitte (2009), p.7).

36. To enable emerging economy players to develop their production capacities, the availability of technologies through licensing from SEFs and chemical companies has played a key role. Chemical plant engineering companies offer a package comprising of core technology, engineering design and knowhow, and contract construction services (Arora (1997), p.396), and are active in developing large and efficient plants being built up in emerging economies (Gottwald, 2007). A study in India on basic chemical firms (inorganic, organic, dyes and pigments, polymers and rubbers) found that acquisition of technological capabilities (through investments on imported technology or in-house R&D) is important in determining export competitiveness. (Bhat and Narayanan, 2009)

37. The entry of emerging market players has exerted strong competitive pressure on chemical producers in developed countries (*e.g.* HLG (2009), p11). The chemicals sector in developed countries, especially in basic and intermediate petrochemicals, has already undergone extensive and continuous organisational changes and rationalisations during the last three decades as a measure to recover cost advantage, driven primarily by competition from new entrants and diminishing economic opportunities after the oil shocks in 1970s. Many companies have moved away from being diversified conglomerates to focus on their core competencies and have sought to reduce over capacities and to achieve scale economies and higher margins (Albach *et al.* (1996), pp. 35-47; Landau and Arora (1998), pp. 11-12; Chapman and Edmond (2000), pp. 755-760)[29].

38. Alongside cost cutting measures such as implementation of lean manufacturing and extension of outsourcing, supply chain management is critical for the industry. Its supply chain extends from raw materials to finished products, and the supply chain management costs represent 8-10 percent of the turnover of chemical companies (KPMG International, 2009d). Facing increased complexity of globalised supply chains coupled with lower margins, several major chemical companies have launched innovative initiatives to optimise their supply chains and cut cost.[30] Information and communication technology is widely introduced to implement process innovation in order to better manage supply chains and distribution networks, improving efficiency and customer satisfaction (PwC (2010a), pp.2-3, KPMG International (2009d), pp. 11-12). Among the US chemical companies, electronic commerce is especially prevalent in basic chemicals, where products are more standardised. Electronic commerce makes up for 23% of the sales in basic chemicals, whereas it is 10% in speciality chemicals (ACC, 2009).

39. Sustainability concerns, alongside cost considerations, are other drivers of process innovation. For example, the application of biotechnology to chemicals production (industrial biotechnology or "white biotechnology" that uses biologically derived catalysts for chemicals production in place of conventional ones and may also replace fossil resources with biomass as raw materials, is expected to make production processes more environmentally friendly (HLG (2009), p.11; OECD (2001a)).[31] OECD (2010) estimates

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[29] Deloitte (2009) shows that the commodity chemicals sector experienced sharper decline in gross margin in 1998-2008 compared with specialty and integrated chemicals companies. *See also* Section IV.3, iii) *infra*.

[30] KPMG International (2009d) cites examples of BASF, the Dow Chemical Company, Eastman Chemical Company and Sumitomo Chemical Co. Ltd.

[31] *See also* Section IV.3, iii) *infra*.

that, although products made by biotechnological processes currently account for only 1.5% in base chemicals (2007), much lower than other segments, this ratio will jump to 10% by 2017. Industrial biotechnology is at an early stage of its technological lifecycle: close collaboration between industry and academia has been playing an important role.[32]

(c) Mergers and Acquisitions (M&A)

40. Acquisition and divestiture of businesses are also often a part of large cost cutting and/or repositioning strategies for chemical companies.[33] Some large chemical companies, such as ICI, have been broken up and/or merged with other companies.

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[32] OECD (2001a) pp.72 and 78 provides examples.

[33] Largest recent examples include acquisition of ICI by AkzoNobel (Box 3) and Rohm and Haas by Dow Chemical in 2008.

Box 3. Imperial Chemical Industries (ICI)

ICI was founded in 1926 in Britain through a merger of smaller firms to become one of the dominant players in the world market in the pre-WWII period, together with IG Farben in Germany (founded in 1925) and DuPont in the United States. Operation of ICI for over 50 years focused on three linked large complexes in Teesside at Billingham, Wilton and North Tees, with a further large facility at Runcorn and other smaller plants around the world. However, ICI progressively withdrew from many of its businesses and employment in chemical industry in Teeside declined from 20 000 to 11 000 between 1981 and 1998. The Wilton site, the largest single-company complex built by ICI in North East England, was transformed and now owned by SembCorp, a company providing engineering and facilities management services, hosting chemical companies including Croda International, Dow, DuPont, Huntsman, and Invista. When ICI was split to form Zeneca (merged with Astra of Sweden in 1999 to form Astra Zeneca) in 1993, ICI was expected to focus on commodity chemicals, yet this was soon reversed to re-focus on speciality chemicals (including businesses bought from Unilever) in order to cope with increasing competitive pressure, until it was finally acquired by AkzoNobel in 2008.

Source: Landau and Arora (1998), p.9; Chapman and Edmond (2000), p.760, Burgess *et al*. (2002), p.204.

41. While the recent downturn has hit the levels of M&A activities, strategic investors have shown relative resilience compared with financial investors. In the peak year of 2007, financial investors accounted for 20% of the deal value, often involving private equity firms. In 2009, the deal value was a quarter of the peak year, and the share of financial investors declined to 13% (Figure 12).[34] This manifestation of tight credit constraints notwithstanding, it may well underestimate the level of activities by financial investors, since they participate in the bidding process and influence prices, even without resulting in acquisition, or they make the deals for minority shares instead of full acquisition. A large deal in 2008 involved acquisition of preferential shares convertible to a 10.4% stake in Dow Chemical. Moreover, some acquirers, strategic investors in themselves, are portfolio companies of private equity firms (financial investors) (PwC, 2009a). On the other hand, as the credit limits make it difficult for the chemical companies to find buyers of their depressed assets, restructuring is also being sought by other means, such as joint ventures, asset swapping and use of sovereign wealth funds (KPMG International (2009b), pp.7-10; Bjacek (2009); Baker (2009), p.31).

42. Emerging economies are entering centre stage in global M&A activities. The levels of M&A activities involving BRICs countries picked up around 2004, about the same time as their acquisition abroad started (Schneider *et al.* 2009). In particular, India has been active in outward investment activities[35] *e.g.* the acquisition by Tata Chemicals of Brunner Mond in 2006 and General Chemical Industrial in 2008, and a more recent bid by Reliance Industries to acquire LyondellBasell Industries in November 2009 (the latter had filed for Chapter 11 bankruptcy protection in January 2009).[36] Among the major motivations for outward investments are thought to be to gain access to knowhow or new markets (Schneider *et al.* (2009), p. 103).[37] The deals involving China have been mainly domestic, with the

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[34] Chemical sector is defined as chemicals and allied products defined by Thomson-Reuters business classification (commodity, agricultural, specialty and diversified chemicals).

[35] KPMG International (2010a) notes that chemicals accounted for 48% of overseas investment (in value) by Indian firms in the last five years (p.11)

[36] This bid was rejected in March 2010. *See e.g.* Joe Leahy (2010), "Reliance pushes for Lyondell catalyst" *the Financial Times*, 20 January 2010; "Lyondell rejects Reliance's $14.5bn bid" *the Financial Times*, 8 March 2010.

[37] Tiwari and Herstatt (2009) found that, concerning direct investment from India to Germany, market-seeking was the dominant investment motivation among IT firms, but technology seeking motivation was more important among automotive sector. *See also* Prahalathan (2007, p.54) for various initiatives of

majority of cross border deals being inbound (*i.e.* foreign firms acquire Chinese businesses; PwC (2009b), p.8). Major Chinese companies have set up joint ventures with global players in China in wide range of products (Table 5; Engman *et al*. 2006, p.125). In one count, a majority of 10 000 chemical units in China are joint ventures (Prahalathan, 2007, p.32). However, outbound activities from China are expected to expand in near future (PwC (2009b), p.3; Shuqing (2009)).

43. This broad development is not over today but has been further intensified by the financial crisis. KPMG International (2009a) predicts that a massive expansion in bulk chemicals in the Middle East to 2015 will make up to 20% of plants of the European petrochemical industry uncompetitive, and that while European and US companies concentrate on portfolio rationalisation and divestiture of distressed assets, cash rich Middle Eastern and Chinese players will move to acquire these assets to gain access to technology and the market over the next one to two years.[38]

Table 5. Major Sino-foreign petrochemical joint ventures

Joint Venture	Participants	Location, Start of operation	Annual production capacity
Fujian Refining & Petrochemical Co. Ltd.	Sinopec, ExxonMobil, Saudi Aramco	Quanzhou city, Fujian Province, 2009	800 000 ton (polyethylene) 400 000 ton (polypropylene) 700 000 ton (paraxylene)
Shanghai SECCO Petrochemical Co. Ltd.	Sinopec, BP	Shanghai Chemical Industrial Park, 2005	900 000 ton (ethylene) 600 000 ton (polyethylene) 250 000 ton (polypropylene)
BASF-YPC Co. Ltd.	Sinopec, BASF	Nanjing City, Jiangsu Province, 2005	600 000 ton (ethylene) 400 000 ton (low-density polyethylene)
CNOOC and Shell Petrochemicals Co.	CNOOC Shell	Dayawan Petrochemical Industrial Park, Guangdong Province, 2006	950 000 ton (ethylene)

Source: Company websites[39]

Box 4. Development in chemical distribution industry

Chemical products have typically been distributed directly from the producers to customers, but this is changing. A study by the Boston Consulting Group (BCG) estimates that this direct supply accounts for 90% of the global distribution, but that distribution through third parties has increased by 10% in 2006-08, higher than the growth rate of chemicals consumption. Industrial chemicals occupy about 60% of the third-party distribution, whereas specialty chemicals make up the remaining 40%.

If the chemical products are very diverse in nature, so are their customers. 20-40% of chemicals are believed to be consumed by customers with annual consumption less than 100 000 euro, depending on the customer industry, and this ratio is much higher in China and Brazil (over 75%). Those smaller customers are at the same time contributors to profit margin for producers due to strong pressures on prices from larger customers. Handling the

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Indian firms for overseas expansion; *The Economist* (2010), *Grow, grow, grow: What makes emergin-market companies run* (15 April 2010).

[38] This has to some extent already been happening in IT/electronics industry, Vance (2010).

[39] Fujian Refining & Petrochemical Co. Ltd: <http://www.exxonmobilchemical.com.cn/China-English/LCW/Files/Corporate/fujian-lamp-2010.pdf>; <http://english.sinopec.com/media_center/news/archive/2009/20090519/7155.shtml >; Shanghai SECCO Petrochemical Co. Ltd: < http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7006982 >; BASF-YPC Co. Ltd: < http://www.basf-ypc.com.cn/en/about_us/company.html>; CNOOC and Shell Petrochemicals Co. < http://www.shell.com/home/content/chemicals/aboutshell/media_centre/media_releases/media_release_archive/2010/pr_successful_turnaround_chinese_joint_venture_nanhai.html >.

distribution for these smaller customers is a particular challenge for the producers, and it has increasingly been outsourced to third-party distributors, aiming to improve cost efficiency by rationalising sales efforts or, in case of emerging markets, to overcome the insufficient sales volume for direct sales.

The business model of chemical distributors is to source from multiple producers to ensure a broad offering; to take physical ownership of products, warehouse them and mix, blend and repackage them to meet the needs of customers; and to sell and physically transport goods to customers. It is distinguished from the business models of logistics-only companies and trading companies, which do not take ownership or offer key value added services such as mixing and blending. These services offered by chemical distributors enable customers to benefit from single sourcing, speed and flexibility of delivery.

The BCG study suggests that there is still room for producers to rationalise their distribution, not only because the process of outsourcing is ongoing but also because many of the producers currently have a complex relationship with multiple distributors due to lack of coordination across business units and regions. It also notes that more acquisitive growth to form a global network will contribute to improve the value and competitiveness of a distribution business, and will meet the expectations of producers and customers better.

During the past several years, M&As in chemical distribution, especially in Europe, has been driven by private equity investors, who were attracted by stable cash flows, limited financial risks and profitable exit prospects of this business. They are active in acquisition of other chemical distributors to seek synergy and to increase market value. The financial crisis also hit the distribution business and M&A activities, but the initial public offering (IPO) of Brenntag AG, the leading chemical distributor and owned by BC Partners Ltd, which raised 747.4 million euros in late March 2010 is expected to raise the prospect of further flotation and consolidation. As the drive for cost efficiency persists on the side of producers, especially in basic industrial chemicals, relations between producers and distributors can become more important than ever before.[40]

ii) Speciality and fine chemicals

(a) Industry characteristics

44. Speciality and fine chemicals are, compared to basic industrial chemicals, higher value-added products produced on a smaller scale in more flexible plants using simpler chemicals as inputs. Examples include dyes, paints, sealants and adhesives as well as certain organic chemicals and petrochemicals (*e.g.* engineering plastics). The products are highly specialised and diverse, designed to perform a particular function to meet the needs of the market or customers, mainly in other industry segments. An essential aspect of the business, therefore, is to sell solutions to customers' problems (Swift (1999), p.35). Products are also formulated as services (known as chemical management services) instead of goods; *e.g.* selling water treatment services instead of selling chemical products for water treatment.[41]

45. In response to increasing competitive pressure in basic industrial chemicals, many chemical companies have been turning to speciality and fine chemicals for their sources of profit where product differentiation rather than cost is the key source of competitive advantage (*e.g.* Burgess *et al*. (2002), p.200). This is especially the case with developed countries, but companies in China, India and Middle East are also seeking to move in this direction (KPMG International (2009b, 2009c), Baker (2009)). The relative flexibility of these production plants makes it easier to introduce new process steps or manufacture a wide range of products.

46. The diversity of speciality and fine chemicals is reflected in the impact of the recession since the last quarter of 2008. The chemicals used in automotives and construction were hardest hit (coatings,

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[40] BCG (2010); Fermont (2007); HLG (2009); "The chemistry of private equity", *Chemistry World* (February 2008); "The time is ripe" *ICIS.com* (23 November 2009); Martin Arnold "Brenntag listing raises 748m for BC Partners", *FT.com* (29 March 2010).

[41] *See* CIGT (2002), p.95 and Upstill (2006), p.21 for more illustrations and examples.

adhesives, sealants), in contrast to those used for personal care, food and pharmaceuticals. But such conventional product segments still do not complete the picture. For example, a number of companies are finding their future in product innovation in environmentally friendly construction chemicals, which are, again, coatings, adhesives, sealants, but designed to be energy efficient, durable and less wasteful, and are actively investing in the development and commercialisation of those products.[42]

(b) The role of product innovation

47. The crucial role of product innovation in speciality and fine chemicals can be seen in the higher proportion of revenues generated from new products than in industrial chemicals (*see supra* Section III.1.(i)). Product innovation in speciality and fine chemicals can serve various purposes. First, as these products are typically designed to achieve certain outcomes (*e.g.* dyeing fabrics, weeding particular plants), new products may be introduced to improve intended performance or to introduce more differentiated quality specifications (grades). Second, new chemicals may be introduced to meet new demands created by innovation in downstream markets. This is typically the case with new active pharmaceutical ingredients supplied to the pharmaceutical industry, but new molecules may be introduced in other sectors to meet new economic and social needs, such as the new demand for environmentally friendly products (*e.g.* fuel cells, organic LED). Third, new chemicals may also be introduced due to their improved performance in the process of production or use by reducing inputs or eliminating harmful constituents. Finally, new products may serve as substitutes for regulated chemicals. This may happen in response to prohibition of some chemicals (*e.g.* CFCs by the Montreal Protocol) or regulation of the way in which products are marketed and consumed (*e.g.* the treatment of effluent or disposal of waste). Trade often serves as a conduit for the fruits of innovation in the chemicals sector to improve performance and foster innovation in downstream sectors.

Box 5. Contribution to GHG Emission Savings in Downstream Industries

Speciality and fine chemicals can serve as an enabler of innovation for their users, beyond the boundary of the chemical industry. Contributing to the reduction of greenhouse gas emissions is one such example.

Speciality and fine chemicals are used for various emission saving technologies and products. A report by the International Council of Chemical Associations (ICCA (2009), p.11) identifies ”the biggest levers evaluated for emissions savings enabled by the chemical industry” including: insulation materials for the construction industry, increased agricultural yields due to crop protection chemicals and fertilisers, new lighting technologies based on compact fluorescent lamps, plastic packaging, marine anti-fouling coatings, synthetic textiles, automotive plastics, low temperature detergents, increased engine efficiency, plastic piping. In aggregate, this ICCA report estimates that for every ton of carbon dioxide emitted by the chemical industry in 2005, it enabled 2.1 to 2.6 tons in savings via the products and technologies it provides to other industries or users.

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[42] ICIS.com (2009), *Deliver the goods* (23 November 2009); ICIS.com (2010), *Green Build up* (15 January 2010).

Box 6. Product Innovation in Response to Regulation and Environmental Concerns[43]

AkzoNobel produces a range of chelating agents, which sequester metal ions in aqueous solutions, for household and industrial cleaning products such as detergent and soap. One of these products, NTA (nitrilotriacetic acid), has been coming under increased regulatory scrutiny in Europe and the United States due to its potential carcinogenic impacts. Since global household product manufacturers who use this do not wish to have multiple formulations in different markets, the product is likely to be phased out including from markets where it does not face regulation.

An alternative product known as Dissolvine GL was developed in 2000. There was initially limited interest from customers to test and approve this product because it was more expensive than NTA, but the prospect of regulation boosted the interest in this product. There was also a potential environmental benefit that drove interest in it, as it can be used as a replacement for some phosphate/phosphonate compounds, which are also under scrutiny in the United States, Canada and France. Unlike NTA which is produced from fossil fuels, this alternative product is made using natural carbon sources from monosodium glutamate derived from food grade molasses, which means that 60% of the carbon atoms in the formulation are derived from sustainable sources and 40% from fossil fuels.

48. Trade not only serves as a channel of the fruits of product innovation, but it can also work to expand the sources of innovative ideas. A survey shows that customers and suppliers are among the most important sources of innovative ideas (after "within the firm") (Eurostat, 2007), but in the chemicals sector 38% of firms who introduced a new product answered that their customers were very important as a source of information for innovation (26% for overall sample).[44] This is particularly true with speciality and fine chemicals, where close customer relationships and servicing are important part of the business (Swift (1999), p.35).

(c) Commoditisation, shift in market gravity and push for further innovation

49. Even in speciality and fine chemicals, products are often eventually commoditised, and it is recognised that this product and technology lifecycle is being shortened thus putting pressure on profits (Baker (2009), p.30; Jerrentrup (2009)), due in part to globalisation. Chinese companies are active in partnership with multinationals to gain access to advanced technologies, alongside in-house R&D (KPMG International (2009c), p.8). They are also pursuing outbound M&A in speciality and fine chemicals, the main motivation of which is considered to be gaining know-how.[45] Indian firms are also active in overseas investment in this segment.[46] A large supply of well qualified chemists and chemical engineers, including in emerging economies, together with the increased numbers of flexible chemical manufacturing facilities in the world means that there is increasing potential for successful products to be copied by competitors (Cesaroni *et al.* (2004), p.127).

50. For example, fine chemical firms who develop and manufacture timber treatment chemicals used to anticipate that it would take six years for them to be commoditised following the entry of low cost

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[43] Information taken from an interview with Alan Alex, Chelates EMEA, AkzoNobel Functional Chemicals, by Paul Wright, external consultant for this study, and AkzoNobel (2009) "Cleaning up", *AkzoNobel Magazine* Issue 3 (November 2009).

[44] Patel (2008), p.66. This percentage is even higher in biotechnology, machinery, automotives and ICT/electronics, which recorded over 40%.

[45] China National Bluestar Corporation took over the Silicone Division of Rhodia, a listed France based speciality chemical company, in October 2006 at 504 million USD. (Schneider *et al.* 2009).

[46] For example, Kiri Dyes & Chemicals acquired Dy Star (Germany) for 70 million USD in March 2010 (KPMG International (2010), pp.7 and 11).

producers abroad. This period of time would give the innovator an opportunity to recoup its research and development costs. More recently, however, this period has shortened to eighteen months, and the returns on product innovation have accordingly fallen for some firms to the point where they can no longer rely on it as a source of competitive advantage.

51. Increased competition makes the case for further innovation even stronger. There has been a wide variation in the performance of speciality and fine chemicals companies during the past 10 years, and innovation to keep up with the market has been a key feature of the top performers (Deloitte (2009), p.16). An econometric analysis at country level (*see* Appendix 2) also lends some support to the concept that innovative capacity (the number of patent applications) is correlated with export and import patterns.[47]

52. However, competition also has an effect of reducing the financial capability to finance R&D expenditure, and the time needed for R&D before commercial implementation is critical in the face of shortened product lifecycle. This necessity for cost and time savings has driven "open innovation" to gain currency (OECD (2008b), p.27): companies increasingly rely on outside innovation for new products and processes. De Wit *et al.* (2007) found that open innovation is particularly frequently observed in development of new technologies in new markets in various sectors albeit to varying degrees.[48] They also found that partners for innovation are influenced by the nature of the project: cooperation with universities and specialised institutes very often takes place in the development of new technologies, whereas the development of new markets with existing technologies takes place in cooperation with other companies.

53. For example, the development of organic semiconductor materials is being undertaken at an international level on various fronts involving large and small companies, often university spin-outs. Partners of cooperation can be within the industry or in other industries in order to seek synergy.[49] Partnership with customers is another possibility, which can foster technological advantages while securing business relations. An econometric analysis (*see* Appendix 2) shows that cross border co-invention[50] has a positive impact on the bilateral trade flows. The causation inferred from the timing of patent application and trade flows appears to be working differently across sub-sectors, but practically, if collaborative activities leading up to patent application is taken into account, such collaborative activities may have implications in fostering trade relations.

54. As the centre of gravity of market shifts to emerging markets, investment in those growing markets has become an important part of business strategy, particularly in the speciality and fine chemicals segment (Baker, 2009; KPMG International, 2010b). Because of the specialised nature of this segment, proximity to customers is often considered imperative (KPMG (2005), p.31; KMPG International (2009c),

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[47] Exporters' patent application is generally positively correlated with trade flows, and importers' patent application is generally negatively correlated with trade flows, although their statistical significance varies depending on the sub-sector and the specification.

[48] This study compares between food, polymers and equipment manufacturing sectors in terms of R&D collaborations. In all sectors collaboration is the highest for "new market, new technology", and it is the highest in equipment manufacturing and the lowest in polymers.

[49] Süd-Chemie and Linde launched a pilot plant in May 2009 for the production of second generation bioethanol from cereal straw. It is expected that Süd-Chemie´s expertise biocatalysis and bioprocess engineering and Linde's experience in implementing chemical and biotechnological processes on a commercial scale will generate synergy (Jerrentrup (2009), p.5; Süd-Chemie (2009)).

[50] It refers to the number of patents invented by a country with at least one inventor located in a foreign country (OECD (2009a), pp.127-28).

p.12) and this relates not only to production but also extends to R&D functions.[51] This can necessitate organisational innovation in making investment decisions and managing extended supply chains.

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[51] *See* KPMG International (2010b), Table 2 for recent announcements by chemical companies to expand their operations in China.

Box 7. Management of Global R&D Investment Decisions in Emerging Economies[52]

AkzoNobel has multiple applications laboratories located in proximity to the customers, such as Houston (for oil field chemicals) and Australia, while retaining the central R&D function in Europe. It is intended to encourage customer oriented development of products and formulations and to ensure routes to the market, being assisted by their distributor and agent networks that identify end use markets and arrange product trials and approvals. Information on the development in those application laboratories are shared across the company through on-line internal forums and regular meetings so that interaction of ideas take place and ultimately achieve a higher success rate and wider adoption of successful ideas.

Geographic segmentation changes with developments in economic reality. China and India are now being considered as separate regions. In order to make better investment decisions in these regions, the company employs a multi-site concept, *i.e.* locating many products on a single site in a concerted fashion instead of letting individual business units decide where to locate new investments.

(d) Process innovation as a differentiation strategy

55. Whilst product innovation is of primary importance, process innovation is another important aspect of innovation in speciality and fine chemicals. It is typically a part of the differentiation strategy rather than for cost reduction purposes, for example by reducing lead-time, or enhancing agility, to better serve customers (Burgess (2002); Guisinger and Ghorashi (2004); Jerrentrup (2009), p.5). Introduction of new products is also often accompanied by the introduction of new processes.

56. Process itself can be a core competence of a chemical company. For example, pharmaceutical companies often invite competent chemical producers to supply samples of specific candidate pharmaceutical chemicals. Suppliers need to undertake high quality synthesis according to the process specified by the pharmaceutical company or by developing their own process, initially at a small scale but eventually it may turn into a larger scale production. Some companies have developed core competence in process technologies to meet such requirements.

iii) Consumer chemicals

(a) Industry characteristics

57. Consumer chemicals are usually formulated products such as personal care products or household products. These are differentiated from other segments in that they are marketed to consumers and customer influence is much greater. Consumer chemicals are often grouped together with food, drinks and tobacco as FMCG (fast moving consumer goods) or consumer packaged products, which is known as the birth place of brand management and renowned for marketing innovation (Crawford *et al*. 2007). Product innovation and underlying R&D capability is also indispensable to respond to diverse and often fluid consumer preference, and to maintain the power of the brand (Jones, 2005). Although consumer chemicals have generally weathered the recession better than others, product innovation that reinforces brand loyalty, such as in the field of natural personal care, will stimulate recovery, as the patterns of recovery from previous recessions attests.[53]

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[52] Information taken from an interview with Alan Alex, Chelates EMEA, AkzoNobel Functional Chemicals, by Paul Wright, an external consultant for this study, and Baker (2009), p.31.

[53] Gillian Morris (2010), "Recession respite", *ICIC.com* (14 April 2010).

58. In addition to consumer chemicals marketed directly to consumers, many chemical companies produce chemical materials for a range of goods marketed to consumers, such as textiles and clothing (chemical fibres and dyes), footwear and car seats (polyurethane). They are typically not visible to consumers, but the materials are sometimes highlighted when the final goods are marketed.

(b) Diversity of consumer preference and emerging markets

59. Although multinationals with well-known brands are active in this area, key success factors are in-depth knowledge of local market and the ability to adjust the products and marketing methods to local consumer preference and other market characteristics. They can be vastly different and at the same time changeable. One example is the sense of hygiene: when the practice of washing bodies with water was out of fashion in Europe, despite the wide-spread practice of bathing in ancient Roman times, perfumes came to the fore among aristocracy, until the practice revived thanks to development of modern germ theory and spread of new ideas brought by foreign trade (*e.g.* "*champu*" (shampoo) from India); the white soap bar was launched by an American entrepreneur in 1879, which later benefited from new marketing channels of radio and television ("soap opera") starting in the 1930s.[54]

60. More recently, social and environmental issues have become an important factor behind consumer preferences, and consumer chemical companies are finding market opportunities here. For example, life-cycle assessments of the energy consumption by Proctor & Gamble for its products found that 3% of electricity budgets in US households were on heating water for laundry (Nidumolu *et al.* (2009), p.8), which led to the launch of cold water detergents in 2005. Unilever considers it important to establish "social missions" for brands to grow (McKinsey & Co., 2009a). In the cosmetics industry, to stimulate sustainable production and consumption, the COSMOS-standard has been developed in Europe that defines minimum requirements and common definitions for organic and/or natural cosmetics. Consumers' attention can go beyond the narrow definition of consumer chemicals, due to the ubiquitous nature of chemical products, and extend to the chemical inputs used in ranges of products, such as polyurethane derived from vegetable used in car seats, biodegradable cosmetic packages, or soy inks. Well-informed, empowered consumers are a powerful ally in supporting and driving green growth (OECD (2010b), p.80).

61. Adding to these, breaking into consumer markets in emerging economies is increasingly an important challenge.[55] They are keener and leaner on prices, and their distribution and marketing channels tend to be very different from those of developed country markets, yet the consumers in emerging markets are increasingly vital sources of further growth, especially amid slower growth in developed countries.[56]

62. For example, expanding the market into more remote areas in India was a challenge due to the lack of a retail network, advertising coverage and adequate roads and transport for Unilever despite its 75 year history in India supplying food, personal care and home care products through a portfolio of international and local brands targeting consumers of different income levels. Hindustan Lever, Unilever's business in India, started "Project Shakti" ("strength" in Sanskrit) in 2000 by partnering with local women's self-help groups. Members of the groups are given training by the company to be entrepreneurs, and they borrow money from the groups to start businesses as distributors of Hindustan Lever products. By the end of 2004, there were over 13 000 Shakti women entrepreneurs covering 50 000 villages, selling to 70 million consumers. (Unilever (a); Keys *et al.* 2009) Hindustan Lever is also developing a separate

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[54] *The Economist* (2009), "The joy of dirt" (17 December 2009).

[55] *See The Economist* (2010), "Easier said than done: Emerging-market consumers are hard to reach" (15 April 2010).

[56] *See also* Figure 4(b) (showing growth rates higher for export from HICs to LMICs than for HICs to HICs in consumer chemicals (HS Chapters 33 and 34) in 2001-08).

campaign to educate people to wash their hands with soap, called "'*Swasthya Chetna*" (health awakening), as a marketing programme for its soap brand. By the end of 2007, the campaign had reached nearly 44 000 villages and around 100 million people. (Unilever (b))

63. Not only marketing innovation, but also product innovation is taking place to develop products that meets the specific needs of emerging markets. Proctor & Gamble started its business in China in 1988 through a joint venture targeting consumers in wealthy coastal cities with its premium products. By 2001, this strategy reached its limits and it needed to expand to the "mid-tier consumers" to sustain growth and profitability, in direct competition with local companies with lower costs and better knowledge about the local consumers. In order to achieve the price levels affordable for these new consumers, which is vastly different from those of globally marketed products, P&G now designs products in China, controlling the costs to meet the required price levels. (Hexter and Woetzel, 2007, pp.6-7)

64. There is an early sign that product innovation and marketing efforts are contributing to the recovery of consumer products companies. Proctor & Gamble and Unilever both announced 7% increases in sales, and the introduction of new products and additional spending on marketing are considered to have boosted the sales, and strong sales growth in emerging markets has contributed to this overall performance.[57]

65. In some cases, products developed for emerging markets are being re-introduced to developed country markets – labelled "trickle-up" innovation or "reverse innovation" to highlight the contrast to a traditional model where a product is developed in developed countries and eventually marketed in developing countries. The reported case that comes close to consumer chemicals is an over-the-counter medicine by Proctor & Gamble, initially developed for the Latin American market and eventually rebranded and marketed in the United States and European markets[58], but otherwise reported cases are still limited.[59] Yet it has been argued that it is more a necessity than an option to compete effectively with emerging market competitors. Given the increasing economic weight of emerging economies and the increasing price-consciousness of consumers in developed countries, as well as tighter R&D budgets of MNEs, this can become one of the models of product innovation in consumer chemicals.

IV. Trade-related measures

1. Tariffs

66. Even though the levels of tariffs have declined over the past ten years, there still remain non-negligible levels of tariffs, especially in non-CTHA participants, that incur direct costs to traders and consequently consumers. Econometric analysis based on the gravity model (Appendix 2) shows that tariffs still have a negative impact on trade in chemicals.

67. In order to see how actual tariff levels are related to innovation considerations, we could test the following two possibilities. First, if countries value technology diffusion through imports (*cf.* Coe *et al.* 2008), they may tend to set up relatively lower trade barriers for sectors with relatively less technological

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[57] Hannah Kuchler (2010), "'Innovation' paying off at Unilever", *FT.com*, 29 April 2010; Jonathan Birchal, "P&G sales surge on new products", and "Emerging markets fuel consumer goods groups", *FT.com*, 29 April 2010.

[58] Jana, Reena (2009a), "Innovation Trickles in a New Direction", *BusinessWeek* 11 March 2009; Jana, Reena (2009b), "P&G's Trickle-up Success: Sweet as Honey", *BusinessWeek* 31 March 2009.

[59] *See* Immelt *et al.* (2009) (health care devices by General Electric); Jana, note 58 (handsets by Nokia and dried noodles by Nestlé).

capability than other domestic sectors. On the other hand, if countries emphasise infant industry protection, they may tend to set up relatively higher trade barriers for less competitive industries (*cf.* Krugman, 1987).

68. A simple investigation of correlation between relative tariff levels, relative export value (*i.e.* revealed comparative advantage) and relative R&D spending shows that there is no statistical evidence to support either of those hypotheses (*see* Appendix 3 for details). This may imply, as far as the chemical industry is concerned, that innovation considerations are not systematic determinants for tariff policy in most of the countries. Another possibility is that innovation considerations are actually systematic determinants for tariff policy but are working in different directions (either technology diffusion enhancing or infant industry protecting) across countries, which also prevent a systematic statistical relationship from emerging as a whole. Definitive conclusions cannot be drawn from the exercise here.

2. Export Restrictive Measures

69. While access to raw materials under fair and undistorted conditions is essential for a range of industries including chemicals, tight supply and demand conditions as well as various forms of government intervention aiming at restricting exports have been making it more challenging than before (European Commission (2008c), pp.4-5).

70. Disciplines on export restrictions are provided generally in GATT Article XI paragraph 1; "No prohibitions or restrictions other than duties, taxes or other charges, whether made effective through quotas, import or export licences or other measures, shall be instituted or maintained by any contracting party on the importation of any product of the territory of any other contracting party or on the exportation or sale for export of any product destined for the territory of any other contracting party."[60] This is, however, subject to an exception in the GATT Artile XI paragraph 2 and general exceptions under GATT Article XX, notably its *chapeau* and (g) ("relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption").

71. Whereas import duties are placed under the disciplines contained in the Schedules of Concession (GATT Article II), there is nothing that generally restricts export duties[61] in the current GATT provisions.[62] It is worth noting, however, commitment by individual Members to limit export duties on specific tariff lines can be found either as a part of accession commitment,[63] or as a part of the Schedules of Concession, with respect to specific tariff lines, although the actual cases are very limited. MFN principle applies also to export duties (GATT Article I.1).

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[60] GATT Article VIII.3(a), 5 (Fees and Formalities connected with Importation and Exportation) and X.1 (Publication and Administration of Trade Regulations) lay out procedural principles that apply to exports as well as imports. In addition, export taxes and export restrictions are listed as one of the "Indicative List of Notifiable Measures" in the "Decision on Notification Procedures" adopted at the end of the Uruguay Round negotiations, although it is accompanied by a note that states "[t]his list does not alter existing notification requirements" in the agreement. "Decision on Notification Procedure on Quantitative Restrictions" was adopted in 1996 (but not on export duties), and the notifications are regularly monitored, although the actual notifications made have been less than complete. *See* G/L/223/Rev.17 (15 March 2010) for the latest update.

[61] Export duties and export taxes have been used interchangeably. *See* Kazeki (2005), pp. 178-79.

[62] In some instances, export restrictions and prohibitions were replaced by export duties following the legal disputes at the WTO. *See* Kazeki (2005), p.212.

[63] Examples are listed in Kazeki (2005), Table 5.4.

72. While the export restrictive measures have thus been subject to a lesser extent of discipline compared with import measures under the GATT/WTO system,[64] it has in the past addressed this issue in the context of supply of raw materials, in particular oil, in the 1970s[65] and of voluntary export restraints in the 1980s[66], and now it is drawing renewed attention in the context of supply of raw materials. The chemical industry has also voiced their concerns over recent moves by some governments to take export restrictive measures, such as export taxes on yellow phosphorus and export licenses or quotas on fluorspar and coke by China, thereby restricting supplies to other countries to, various raw materials (HLG (2009), p.33). When the raw material production is concentrated in a few countries (Table 6), export restrictive measures taken by a producing country can have a large impact on the global supply, and hence on the industries using the raw materials in question.

73. In the WTO, proposals to enhance transparency in export licensing and to establish of rules on transparency and predictability on export duties are pending in the Doha negotiations.[67] Export related measures on raw materials are also pending before the dispute settlement panel, which covers, in part, essential inputs to some segments of the chemicals industry and inorganic chemicals used in other industries.[68]

74. While the stated policy objectives of export restrictive measures include environmental protection, promotion of domestic downstream industries, fiscal revenues and preservation of reserves, the actual economic impact of export restrictive measures and their effectiveness in achieving these objectives depends on various factors, such as supply and demand conditions, availability of alternative sources as well as the nature of the raw material in question and of the measure itself (Korinek and Kim (2009), pp.12-22). The trade policy review report on China prepared by the WTO Secretariat observed "[a]lthough the authorities believe that export taxes could help conserve natural resources or protect the environment, their economic effectiveness in achieving those objectives is questionable." (WTO (2010a), para. 78) At the OECD workshop on raw materials held in October 2009, it was found that "export restrictions create economic inefficiency by distorting resource allocation and can negatively affect the welfare of trade partners" and "[w]hile export restrictions are applied to achieve several policy objectives, there exist alternative policy options with different trade impacts" (Kim, 2009).[69] Further studies are envisaged on this topic.

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[64] Despite this asymmetry between exports and imports, economic theory postulates that export tax in one sector amounts to import tax on the other (Lerner's symmetry theorem), which further implies that import tax in one sector amounts to export tax on the other. *See* Vousden (1990), pp.46-47.

[65] The issue of export restrictions was negotiated in the Tokyo Round, but it only resulted in an understanding that the GATT export provisions should be reassessed in the near future. Jackson *et al.* (1995), p.947.

[66] Japan – Trade in Semi-Conductors, Report of the Panel adopted on 4 May 1988 (L/6309 – BISD 35S/116); *See also* the Agreement on Safeguards Article 11, paragraph 1(b).

[67] "Protocol on Transparency in Export Licensing to the General Agreement on Tariffs and Trade 1994", submitted by Chinese Taipei, Japan, Korea Ukraine and the United States (TN/MA/W/15/Add.4/Rev.5, 5 February 2010); "Revised Submission on Export Taxes", submitted by the European Communities (TN/MA/W/101, 17 January 2008).

[68] China – Measures related to the exportation of various raw materials (DS 304, 305, 398), brought by the European Communities, Mexico and the United States.

[69] *See also* WTO (2010c), note 15.

Table 6. Production and Reserves of Phosphate Rock (million metric tons) and Fluorspar (thousand metric tons)

Phosphate Rock	Mine production			Reserves	Fluorspar	Mine production			Reserves
	2008	2009	share			2008	2009	share	
China	50.7	55.0	35%	3 700	**China**	3 250	3 000	59%	21 000
United States	30.2	27.2	17%	1 100	**Mexico**	1 060	925	18%	32 000
Morocco	25.0	24.0	15%	5 700	**Mongolia**	380	280	5%	12 000
Russia	10.4	9.0	6%	200	**Russia**	269	210	4%	NA
Tunisia	8.0	7.0	4%	100	**South Africa**	316	180	4%	41 000

Source: USGS Minerals Yearbook, Mineral Commodity Summaries 2010.

Note: The figures for 2009 are estimates. Production data for China do not include small "artisanal" mines. Fluorspar reserves are measured as 100% calcium fluoride. % share in 2009.

3. Health, safety and environmental regulation

i) Regulation and multilateral trade rules

75. The chemical sector is highly regulated for safety, health and environmental reasons and there has been significant evolution in the regulatory regime during the past few decades. When governments started to take regulatory actions on chemicals, they focused on specific industrial chemicals or pesticides which were known to pose important health or environmental problems, but by mid-1970s, comprehensive, forward-looking strategies were called for to identify and manage the potential risks of the hundreds of new chemicals and chemical products entering the global market every year. Somewhat later, the much greater number of chemicals and pesticides that were already on the market and whose potential risks had not been identified arose as a policy issue (OECD (2001b), p.76). The OECD has been active since 1971 in developing and co-ordinating chemical and pesticide related activities under its Chemicals Programme (OECD (2008c), p.383). There are a number of other international arrangements to control chemicals for various purposes.[70]

76. The World Summit on Sustainable Development (WSSD) in 2002 called for chemicals to be produced and used in ways that minimise significant adverse impacts on human health and the environment ("2020 goal"). Since then, many countries have taken steps to improve their chemicals regulation. Also, the Strategic Approach to International Chemicals Management (SAICM) was adopted as a policy framework to foster the sound management of chemicals in 2006.

77. Under the rules of the WTO, Members are generally able to take measures necessary to protect human, animal or plant life or health, "[s]ubject to the requirement that such measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade" (GATT Article XX, chapeau and (b)). More specifically, the Agreement on Technical Barriers to Trade ("TBT Agreement")

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[70] *E.g.* the Basel Convention (hazardous waste), the Montreal Protocol (CFCs) and the Rotterdam Convention (hazardous chemicals), Stockholm Convention (persistent organic pollutants), United Nations Convention Against Illicit Traffic in Narcotic Drugs and Psychotropic Substances (drug control) and the Chemical Weapons Convention (arms control).

stipulates a set of rules to ensure that technical regulations and standards do not create unnecessary obstacles to international trade, while recognising the policy objectives of the protection of human, animal or plant life or health, of the environment (TBT Agreement, preamble). It lays out, among others, a notification procedure for technical regulations when a relevant international standard does not exist and if the technical regulation may have a significant effect on the trade (TBT Agreement, Article 2.9; Article 5.6 for conformity assessment procedures).

78. According to the TBT Information Management System, database maintained by the WTO Secretariat, there have been over 1600 notifications under Article 2.9 and 140 notifications under Article 5.6 for chemicals (HS Chapters 28-39) since the WTO came into being in 1995.[71] Almost half of them refer to human health, followed by environmental protection and labelling. The pattern is substantially different across different product groups; “human health” predominant in pharmaceuticals and cosmetics (Chapters 30 and 33), while both “human health” and “environmental protection” often appear miscellaneous chemicals (Chapter 38; often pesticides) as well as for organic and inorganic, fertilisers and paints (Chapters 28, 29, 31, 32). In contrast, “labelling”, “safety”, “packaging” and “consumer protection” are more frequent for consumer chemicals.

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[71] *See also* the note for Table 4 for details. Similar study is done by Menezes and Antunes (2005). *See* WTO (2005a), pp.58-62, for various measurements of standardisation activities.

Table 7. TBT Agreement article 2.9.2 Notifications by key words (HS chapters 28-39)

HS	Notifications, total	Notifications by key words									
		human health	environmental protect-tion	labelling	safety	packaging	consumer protection	quality requirements	hazardous substances	food standards	toxic substances
28	90	36	29	14	8	14	6	14	10	1	8
29	135	44	55	14	11	2	10	1	13	7	18
30	439	340	11	66	7	26	36	51	0	3	0
31	94	44	53	21	1	15	6	4	0	1	0
32	96	46	33	18	10	10	12	3	19	0	4
33	158	122	2	42	7	7	24	10	5	4	0
34	105	57	15	35	12	13	25	6	4	0	1
35	22	5	1	12	5	3	11	3	4	8	1
36	67	4	1	21	39	9	12	2	0	0	0
37	2	0	0	0	0	0	0	0	0	0	0
38	350	215	223	69	33	58	16	48	12	4	7
39	200	30	30	26	61	35	45	9	4	41	2
total	1 627	880	439	303	180	180	174	142	60	65	33

Source: TBT Information Management System, WTO (as of February 2010)

Note: Searched for covered products by HS Chapters 28-39 (*see* Table 1 for descriptions of HS Chapters). “Total” shows the notifications for the entire Chapters 28-39, which does not equal the sum of notifications for each Chapter due to duplications. There are some notifications that specify “chemicals” as covered products but do not appear in search results by HS Chapters, which are not included in this table. There are also many notifications without key words recorded in the database. Finally, although notification is a requirement under the TBT Agreement, in practice there can be delays in notifications from Member governments. Such regulations not notified to the WTO are not captured in the table.

79. Chemicals have been extensively discussed in the meetings of WTO’s Committee on Technical Barriers to Trade (TBT Committee).[72] Table 8 summarises the chemical-related “specific trade concerns” raised in the Committee meetings in 2009. In addition to these, the trade related measures on chemicals in China (Regulations for Environmental Management on the First Import of Chemicals and the Import and Export of Toxic Chemicals) and its ongoing revision have been regularly raised in the context of Annual Transitional Review (TRM) of China’s accession commitment.[73] TBT-related issues involving the chemicals have also being discussed in the DDA/NAMA negotiations, and two text proposals have been put on the table.[74]

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[72] *See e.g.* WTO, *Chemicals and toys main focus of members’ trade concerns*, 20 March 2008 < http://www.wto.org/english/news_e/news08_e/tbt_20march08_e.htm>; WTO (2009a), paras. 73-75.

[73] *See e.g.* WTO, Committee on Technical Barriers to Trade, Minutes of the Meeting of 5-6 November 2008 (G/TBT/M/46), 23 January 2009; Minutes of the Meeting of 5-6 November 2009 (G/TBT/M/49), 22 December 2009.

[74] “Understanding to facilitate the implementation nof the TBT Agreement as applied to trade in the chemical products sector”, submitted by Argentina and Brazil (TN/MA/W/135), 4 February 2010; “Understanding on Non-Tariff Bariers Pertaining to Standards, Technical Regulations and Conformity Assessment Procedures for Chemical Products”, submitted by the European Union (TN/MA/W/137), 19 March 2010.

Table 8. Specific Trade Concerns raised in 2009 at the TBT Committee meetings involving chemicals[75]

Member taking the measure, the measure involved	Raised by	First raised
Chile - Cosmetics	European Union	2009
European Union – Biocide Dimethylfumarate	Japan	2009
European Union – Decision on Restrictions of the Marketing and Use of Organostannic Compounds	Japan	2009
Indonesia – Regulation of BPOM No. HK.00.05.1.23.3516 relating to distribution license requirements for certain drug products, cosmetics, food supplements, and food	European Union, United States	2009
Argentina – Measures affecting market access for pharmaceutical products	Colombia, Chile, Paraguay	2007
European Union – Directive 2002/95/EC on the Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) and Directive 2002/96/EC on Waste	Australia, Canada, China, Egypt, Japan, Jordan, Korea, Malaysia, Mexico, Thailand, United States, Venezuela	1999
European Union – Regulation on the Registration, Evaluation and Authorization of Chemicals (REACH)	Argentina, Australia, Botswana, Brazil, Canada, Chile, China, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Egypt, El Salvador, Indonesia, Israel, Japan, Korea, Kuwait, Malaysia, Mexico, Pakistan, Philippines, Qatar, Saudi Arabia, Singapore, South Africa, Switzerland, Chinese Taipei, Thailand, United States, Uruguay	2003
European Union – Regulation on Classification, Labelling and Packaging of Substances and Mixtures (ATPs and CLP)	Argentina, Australia, Botswana, Brazil, Canada, Chile, China, Colombia, Cuba, Dominican Republic, Ecuador, Indonesia, India, Japan, Korea, Malaysia, Mauritius, Philippines, South Africa, Chinese Taipei, Thailand, Turkey, United States, Venezuela, Zimbabwe	2007
India – Drugs and Cosmetics Rules 2007	European Union, United States	2007
Norway – Proposed regulation concerning specific hazardous substances in consumer products	Israel, Korea, Japan. Jordan, United States	2007
United States – Consumer Product Safety Improvement Act	China	2008

ii) Chemicals regulation and impact on innovation

80. The rules of the WTO are an instrument to balance the objectives of protecting health, safety and environment and trade liberalisation.[76] On the other hand, whether and to what extent environmental regulations and innovation interact with each other has been extensively debated and analysed. While empirical analysis on the chemical regulation has not been abundant (Mahdi (2002), p.9-16), the recent regulatory developments in the chemicals sector have drawn much attention.

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[75] Excerpt from WTO (2010b), pp.25-35.

[76] Another instrument are the OECD Guiding Principles for Regulatory Quality and Performance (OECD 2005b), as concerns to market openness. The impact of standards on trade flows depends on their specific types. WTO (2005b), pp.57-74 provides an overview.

81. The chemicals regulations in OECD countries have typically been designed as follows: Governments collected data from chemical manufacturers to establish inventories of chemicals currently being produced, thereby establishing the distinction between "existing" (on the inventory) and "new" (not on the inventory) chemicals. Pre-market notification and registration/approval systems for industrial chemicals and pesticides are in place in most OECD countries, and submission of information is required for the authorities to assess the risks posed by the substance. This data requirement varies across countries. On the other hand, prior to the introduction of pre-market regulation, chemicals were allowed to be put on the market with very little or no information concerning their potential risks to human health and the environment (OECD (2001b), pp.76-78). Major policy questions have been raised regarding this regulatory scheme, such as the adequacy of risk assessment of new chemicals (data requirement from the businesses and allocation of responsibilities between the authorities and businesses) and how to ensure the safety of the existing chemicals (*see e.g.* European Commission (2001), p.6; USGAO (2007); USGAO (2009), pp.22-24).

82. In recent years, various initiatives have been introduced in many jurisdictions regarding chemicals regulations. Among them, the EU's REACH regulation, entered into force on 1 June 2007, has been widely expected to bring about a sea change in chemicals regulation in Europe and will also have global impact. It covers all substances, new and old, unless explicitly exempted, and introduces a registration scheme that requires manufacturers and importers to obtain relevant information (technical dossier or chemical safety report, depending on the quantity) on their substance as well as an authorisation system for substances of very high concern. Downstream users are also brought into the system and share certain responsibilities (European Commission (2007), pp.5-7). REACH has been a major issue of discussion at the WTO's TBT Committee.[77] Many non-EU WTO Members raised questions around, among others, the data generation requirements under REACH in relation to the obligations of non-discrimination and of not creating unnecessary obstacles to international trade according to terms of the TBT Agreement.

83. Aside from the debate at the WTO, the REACH legislation has proven an important development for regulators in exploring the possible regulatory initiatives on the chemical substances.[78] There have been a number of regulatory initiatives in recent years, and following is some of such examples.

84. China has been preparing the amendment to its chemical control scheme under Measures on Environmental Management of New Chemical Substances, introduced in 2003.[79] The first draft released in May 2009 was updated in January 2010, and it is scheduled to be implemented starting October 2010. The amendment maintains the basic structure of the current law, which applies to "new" substances, and "registration certificate" of the new substance is required before manufacture or import of the substance. The revision, on the other hand, is to increase the data requirement and risk management obligations by the industry (Freshfields Bruckhaus Deringer, 2009). Certain ecotoxicological testing needs to be completed at an accredited Chinese testing laboratory by using species within domestic China, and unlike the current law, only a Chinese-registered entity can perform a submission and will be considered the registrant of the substance (Bergeson & Campbell, P.C. 2010).

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[77] Motaal (2009), pp.649-657. It was notified to the TBT Committee in 2004 (G/TBT/N/EEC/52 (21 January 2004)).

[78] *See* USGAO (2007, 2009); Naiki (2010) (for impact on Japanese regulation); Park (2009) (for impact on regulation in China, Japan and Korea); and Heyvaert (2009) (on dynamics of globalisation of regulation).

[79] It should be noted, however, that this "Measures" is not the only chemical regulation in China. *See* Park (2009), Table 1 and Figure 2 for an overview of the structure of Chinese chemical control system.

85. Japan enacted an amendment to the Chemical Substances Control Law (*Kashinho*) in 2009 and the first phase of implementation started in April 2010 (its full implementation is scheduled in April 2011). It introduced an annual notification of production and import quantity of all chemical substances above threshold, and hazard information may be requested for substances of higher priority of risk assessment.[80] In parallel, collection of safety information on the prioritised existing chemicals is ongoing under the "Japan Challenge" programme since 2005.

86. Canada launched the Chemicals Management Plan in December 2006, under which harmful chemicals were regulated immediately, and collection of information ("challenge") on the properties and uses is ongoing for the approximately 200 substances of highest priority. The information will be used to decide the best approach to protect health and the environment (Government of Canada, 2009).

87. The US Environmental Protection Agency (EPA) announced Essential Principles for Reform of Chemicals Management Legislation in September 2009, setting out Administration goals to strengthen the chemicals regulation, which includes a requirement for manufacturers to provide sufficient hazard, exposure and use data on new and existing chemicals to determine their safety, and authority of EPA to set priorities for conducting safety reviews on existing chemicals. In parallel, it announced the Chemical Management Program which includes risk management on specific chemicals, collection of information to prioritise chemicals for review and give public access to information.

88. The consequence of the regulation was extensively discussed in the preparatory process of REACH since the concept was unveiled in 2001 (European Commission (2001)). KPMG (2005), commissioned by the European Commission and European industry groups, found that (a) critical substances are not likely to disappear because of REACH testing and registration costs, because suppliers are well aware of the impact of withdrawal of substances to the downstream users; (b) as product cost will increase because of registration requirement, especially for substances manufactured or imported in lower volumes, rationalisation of product portfolios may take place primarily on substances of less critical importance to customers and of less strategic importance within the portfolios; even a small percentage of withdrawal can give rise to much larger need for reformulation downstream; (c) companies studied do not plan to increase their R&D budget, and they will give priority to keeping existing substances and formulations on the market to avoid problems down the supply chain, so the scale of divergence of R&D budgets depends on the scope of rationalisation; there can also be some delay in the time-to-market as the R&D department will get involved in registration activities; and (d) the stress factors accumulate at SMEs.

89. The recent regulatory initiatives reviewed above generally point to (a) enhancement of data collection of chemical substances, although with considerable differences in scope and data requirements, and (b) extension of regulatory coverage to the existing chemicals. Their impact can be thought of in terms of both the "rate" of innovation and the "direction" of innovation (*cf.* Mahdi (2002), p.9). First, if new regulations involve additional cost and time burdens, they may have a negative effect on innovative activities (rate of innovation). Second, new regulations may give incentives toward safer and more environmentally friendly chemicals (direction of innovation).

90. First, the impact of additional cost and time on innovation is likely to be different for different sub-sectors. For industrial chemicals, as most of their products are in the "existing" category, if new chemical regulation is to require submission of data on all chemicals, this will mean additional cost which was not foreseen before, and because of the standardised nature of the products competing on prices, transferring additional cost onto prices could be difficult. On the other hand, because of their large scale

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[80] METI *et al,* (2009); *See* Naiki (2010) for a comparative analysis of Japanese chemicals regulation and REACH.

production, the additional cost can be mitigated by the economies of scale (Frohwein and Hansjürgens (2004), pp.30-31).

91. In contrast, for speciality and fine chemicals, characterised by continuous product innovation, product differentiation and small scale production, if a new regulation incurs additional time and greater cost to registration and authorisation of new chemicals than before, this may delay or discourage the introduction of new chemicals. If the new regulation extends to existing chemicals, additional regulatory burden may result in rationalisation of portfolio of chemicals in the market, especially for low-volume or low-margin products. As a quick and flexible response to specific and low-volume customer needs is based on the availability of a large pool of differentiated chemical substances, if new regulation diminishes the existing and future chemical portfolio, it can adversely affect the competitiveness in this segment and can impair the prospect of further innovation. And this, unlike the one-off cost of registration, can leave a lasting effect. (Frohwein and Hansjürgens (2004), pp.31-32; Feldmeier and Kienert (2008)) The practical effect on innovation depends on the actual time and cost burden and to what extent such rationalisation takes place.[81]

92. Second, regulatory tightening can encourage the innovative efforts toward safer products.[82] Such regulatory measures are not limited to outright restrictions of hazardous chemicals but can include various other types of measures. Koch and Ashford (2005, pp.43-44) reports the effects of the Massachusetts Toxics Use Reduction Act (TURA) passed in 1989, which introduced a requirement for firms to prepare a Toxics Use Reduction Plan to show how toxic chemicals are used and how they could be reduced. Out of 1 000 facilities that took part in the reporting, 400 have quit using the reported chemicals, and the estimated cost savings by the firms by implementing safer alternative production process exceeded the estimated regulatory cost between 1990-97.[83] Access to information is another type of measure. Since the information collected by the regulatory authority contains useful information for the downstream businesses and consumers, such information is often made publicly accessible within the limits of protection of confidential business information. For example, exposure profiles of individual substances and their toxicity and inflammability gives the opportunity for the users of the substances to avoid the risks, by not using the substance or properly devising the risk management of the substance. This can, in turn, provide incentives for the manufacturers to search for safer alternatives (Koch and Ashford (2005), p.41).[84]

93. Chemicals regulation should be designed to be non-market distorting to be efficient, innovation-friendly and promote long-term solutions.[85] As pointed out in the Interim Report on the Green Growth Strategy by the OECD, the creation of unintended distortions or unnecessary administrative burdens impedes dynamic economic efficiency, and the competitive business environment supports the achievement of environmental goals in a cost effective way (OECD (2010b), pp.77-78). Practically, the impact of the recent development in the chemicals regulation needs some more time to observe, since they are still at an early stage of implementation or preparation. In the case of REACH, for example,

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[81] European Commission (2007, p.16) expects substances withdrawn because their continued production would not be profitable to be 1-2%. It also notes that as a result of the KPMG (2005) study cited above, registration costs for lower tonnage substances have been substantially reduced, largely through reducing the number of substances requiring any toxicology testing (*ibid.*).

[82] Substitution of hazardous chemicals is stated as one of the key elements for REACH (European Commission (2001), p.8; European Commission (2009a), p.5).

[83] In the case of REACH, authorisation is required for substances of very high concern, and application for authorisation need to include an analysis of possible substitutes, and if suitable alternatives are available then the application must also include a substitution plan. (European Commission (2007), p.13)

[84] *See also* discussions on speciality and fine chemicals and consumer chemicals, *supra* Section III.2.

[85] *See cf.* discussions on export restrictive measures (IV.2) and climate change, *infra*.

registration of 30 000 substances is scheduled to take place in three stages over the first 11 years after entry into force (European Commission, 2007). It is therefore necessary to keep track of those developments in order to properly assess their full impact.[86]

Box 8. A short review of the literature on the impact of environmental regulation on innovation

Regulation has typically been seen as a source of concern in terms of competitiveness of industries, since it imposes extra cost and time burden and diverts resources away from innovation. However, Porter and van der Linde (1995, p.98) presented an entirely opposite view, arguing that "properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them" because "reducing pollution is often coincident with improving the productivity with which resources are used" drawing on examples to support this "Porter hypothesis". [87]

The impact of environmental regulation on innovation has also been a subject of economic analyses (Jaffe *et al*. 2000, pp. 31, 65). There have been a substantial number of studies that suggests that more stringent environmental regulation or higher electricity prices induce innovative activities and enhance energy efficiency (Popp *et al*. 2009, pp.7-23); if not completely "offset" the compliance cost that Porter hypothesis alluded to. The impact of regulation can even go beyond the national border. One such example is car emissions regulations in the United States in 1970s, which prompted innovation by Japanese and German automotive industries (*ibid*. p.36). It is important to note that an empirical study on this question should be read in its specific context; all environmental regulations are not created equal, and their impact on industries[88] and their responses are not the same.

Academic debates aside, businesses have already been embracing environmental and social issues even without regulations and many of them recognise the business benefits[89] (McKinsey & Co., 2009b, 2010; KPMG International, 2009b, pp.12-14), and better ways to integrate them as a driver of innovation and to link to corporate strategy are being explored (Porter and Kramer, 2006; Nidumolu *et al.* 2009).

As business takes initiatives to improve its performance and governments act to address market failures, which includes both environmental (negative) externalities and of knowledge diffusion leading to innovation (positive externalities)[90] by introducing regulation, the impact of regulation on innovation remains a valid area of research. From a policy standpoint, integrating both economic and environmental considerations in regulatory decision-making is a challenge, and it is a key feature of the green growth strategy that the OECD is developing (OECD (2010b), p.77).

iii) Climate change

94. The climate change conference in Copenhagen in December 2009 produced the Copenhagen Accord, which includes the recognition that the increase in global temperature should be below 2 degrees Celsius, a collective commitment by developed countries to provide new and additional resources approaching USD 30 billion for the period 2010–12, and implementation and reporting of reduction and mitigation of emissions. As this is not considered a full agreement, the negotiation process is expected to continue toward the next conference in Mexico in 2010. On the other hand, the EU Emissions Trading

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[86] Pre-registration was due on 1 December 2008, and registration for the first batch of chemicals will be due on 30 November 2010. The final due date will be 31 May 2018.

[87] *See cf.* Paul Krugman, "An Affordable Truth", *the New York Times*, 7 December 2009 (referring to an impact of cap-and-trade system for sulphur dioxide in the United States in 1990).

[88] Jaffe *et al*. (1995), p.141, reports sectoral disaggregation of pollution abatement expenditures in the United States in 1992.

[89] KPMG International (2009b) for chemical industry; McKinsey & Co. (2009b) for survey results, and *The Economist,* "Size Matters" (4 December 2009) for consumer electronics.

[90] *See* Popp *et al*. (2009), pp.3-6 for fundamentals of economics of environment and technological change.

Scheme (ETS) has been in effect since 2005 and is scheduled to be expanded in 2013. A trial implementation of an integrated domestic market for emissions trading started in Japan in October 2008. Introduction of cap-and-trade system is also a priority of the current US administration.[91]

95. The chemical industry is in a unique position as both a major industry sector in terms of energy use and CO2 emissions and as a major contributor to deliver solutions to climate change (CEFIC (2008b); KPMG International (2009b), pp.12-14). The chemical industry uses minerals and fossil hydrocarbons (natural gas and oil) as raw materials which are transformed into more complex molecules and polymers. Nearly 60% of total energy products (coal, oil products, natural gas, electricity and renewables) are used as feedstock, and a little over 40% are used as fuel and power in the European chemical industry (CEFIC (2009), p.32). The short-term profitability of the industry is directly linked to fluctuations in raw material and energy prices, and in the long-run the sustainability of the current dependence upon non-renewable fossil fuels as raw materials is increasingly questioned.

96. Extensive studies are underway about the possible use of biomass as a new source of feedstock with a view to reducing the industry's reliance on fossil fuels.[92] One study (Patel *et al.* 2006) on the potential impact of use of biomass-derived feedstock to convert into organic bulk chemicals by means of White Biotechnology (by fermentation or enzymatic conversion) found that up to two thirds of the current non-renewable energy use for the production of the selected chemicals could be saved by 2050. Should this projection become reality, significant technological breakthroughs are required as well as favourable relative prices between fossil fuels and fermented sugar.

97. The demand for a more sustainable use of resources and mitigation of climate change impacts, alongside the competition from emerging economies, further adds to the importance of innovation (HLG (2009), p.11).[93] Policy measures such as the ETS will give incentives to the search for emission reducing technologies (OECD (2009b), pp.63-64). At the same time, technology policy to harness creation of environmental-friendly technologies[94] and an open trade policy to facilitate adoption of environmental-

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[91] "And, yes, it means passing a comprehensive energy and climate bill with incentives that will finally make clean energy the profitable kind of energy in America. I am grateful to the House for passing such a bill last year. And this year I'm eager to help advance the bipartisan effort in the Senate." The State of the Union Address by President Obama, January 2010.

[92] *See e.g.* European Commission (2008) (on biotechnology in Seventh Framework Programme of Research); SusChem (2008).

[93] HLG (2009, p.25) pointed out the possibility of carbon leakage in chemicals sector should be taken into account under the ETS Directive. On the other hand, OECD (2009b, Chapter 3) estimated that, while insufficient participation in global carbon pricing policy can result in non-negligible carbon leakage (12% leakage rates in 2050), broader participation will render the size of leakage much smaller (1.7%). Di Maria and van der Werf (2008) further shows that induced technological change in energy saving technologies will offset or at least mitigate the effect of carbon leakage. *See* WTO and UNEP (2009), pp.98-110 for a survey of the issue and relevance to WTO rules.

[94] Aghion *et al*. (2009) stresses that, in order to foster emergence of green innovation, climate change policy should combine a carbon price with high initial clean-innovation R&D subsidies, rather than relying solely on carbon price, given the current carbon market under the ETS where the carbon price is low, highly volatile and not predictable. Popp *et al.* (2009, pp.4-5) also argues, based on various studies, that environmental and technology policies work best in tandem. This is because while technology policy can help creation of new environmental-friendly technologies, environmental policy should be in place to encourage adoption of these technologies; on the other hand, it is suboptimal to raise emission tax above the level necessary to account for the environmental externality, and targeted technology policy should accomplish technology creation and spillovers.

friendly products and technologies will also play essential roles.[95] For example, electric power plants in India have been using domestically produced coal because imports were virtually banned to protect the domestic industry, but emissions could have been reduced by using high quality imported coal (Khanna and Zilberman, 2001). Another study further found that access to technologies, facilitated by openness to international trade, further facilitates countries to adopt environmental regulation at lower levels of per capita income (Lovely and Popp, 2008). International effort, including trade liberalisation through WTO negotiations, can play an important role to accelerate the diffusion of climate change mitigation technologies (Newell (2008), pp.13-14).[96]

4. Intellectual property

i) The role of intellectual property in the chemicals industry

98. Intellectual property is an important resource generally and the availability of protection for this resource can help to spur innovation; this is also the case with the chemicals sector.[97] For example, in basic industrial chemicals, process technology is the key to cost leadership, and technology licensing has become a business in its own right. Protection of brands is important especially for consumer chemicals where it can contribute to brand loyalty and consumer protection. Various types of know-how (technical and commercial) gained through experience are also valuable resources that merit protection.

99. But the characteristics of the chemical sector make intellectual property all the more important because of the relative ease of producing many types of chemicals once the necessary technologies are known (Cesaroni *et al.* (2004), p.126). Therefore, firms seek to protect as intellectual property their knowledge concerning the composition and formulation of chemical products.

100. Technologies may be protected by patents or trade secrets, and both have been extensively used throughout the history of the chemical industry, whereby the choice may depend on the nature of the technology and the strategy in the specific situation. Some knowledge is relatively difficult to protect through patents, particularly if it is difficult to codify. In some cases, disclosure requirements under patent law may be seen as increasing the risk of imitation. A logical consequence of such considerations is for firms to patent the technology which can be clearly articulated, and keep the rest as secret (Arora (1997), p.393). In addition, development and defence of patents can be very resource intensive, which may contribute to the lower propensity of smaller firms to patent their innovations.

101. Nevertheless, patents play an important role in allowing the chemical industry to protect and utilise the innovation. For example, wide spread technology licensing by SEFs is facilitated by patents (Arora (1997), p.396).[98] Chemistry is one of the major areas of patented technology, representing 14% of world patent applications (Figure 13). Individual firms may hold thousands of patents. For example, in 2008 DuPont alone filed over 1 900 US patent applications and was granted 495 patents; it currently holds more than 6 000 active U.S. patents (ACC). Overall, the majority of patent applications in chemistry (2007) take place in such areas as organic chemistry (4.7%), organic macromolecular compounds (2.4%) and biochemistry (3.0%).

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[95] WTO and UNEP (2009), pp.61-62.

[96] *See also* Chairman's summary at the Seventh WTO Ministerial Conference (WT/MIN(09)/18, 2 December 2009).

[97] *See c.f.,* CEFIC (2008a).

[98] This is consistent with more general observation that stronger intellectual property rights have a positive effect on technology transfer via licensing. *See* Park and Lippoldt (2005).

102. Three quarters of patent applications in chemicals are made by the United States, Japan and Germany. While these countries lead the field with respect to patents, in recent years new entrants, such as India, Korea and China, have gained weight especially in organic and fine chemistry. International R&D cooperation is gradually gaining ground in these areas, as the ratio of co-patenting (the patents with at least one foreign co-inventor) stood at around 12% and has been edging up since the 1990s (Figure 14). There are considerable variations in the pattern of co-invention across countries. In general, countries with larger number of patents are lower in their ratio of co-invention. Countries that tend to be relatively low in their tendency to co-invention include for example Japan, India and Korea; China is a contrasting example, with a large volume of patent applications, whereby almost half resulted from co-invention (Figure 15).

103. An econometric analysis (Appendix 2) shows that the number of patent applications has certain correlations with export and import patterns, and that co-patenting is positively related to bilateral trade. The dynamics between co-invention and trade flows appear to be different in different sub-segments, but it may imply in practice that collaborative efforts leading up to patent application may foster trade flows, or trade flows and collaborative innovation are mutually reinforcing and go hand-in-hand (especially in basic materials).

104. The high ratio of co-invention in China may be explained as a natural development, but it appears that it may also be driven by policy. In China, preferential tax treatment is provided to those who offer intellectual property, R&D capabilities or advanced technology (PwC (2008a), p.5). On the other hand, this is sometimes viewed as a requirement to establish a large scale R&D facility, that is a significant cost that comes with entry into China (PwC (2008a), p.12), which may inhibit inward investment.

ii) Problems with protection and infringement

105. Since the TRIPS Agreement entered into force in 1995, developing countries have undertaken significant reforms in their intellectual property systems (Park and Lippoldt (2008), p.18). For example, patent protection for pharmaceuticals, food and chemical based products in India under the Patent Act of 1970 was limited to process patents; product patents were not available for these sectors. As this allowed "reverse engineering" of drugs patented elsewhere, it effectively kept new drugs by multinationals out of the Indian market, and this in turn gave the indigenous pharmaceutical production an opportunity to take root (Prahalathan and Baruah (2007), p.47-51). The Patent Act of 2005 changed this domestic rule and extended the scope of product patent to those sectors to be in line with the TRIPS Agreement (*ibid.*, p.64).[99]

106. Despite these major improvements in statutory protection, implementation remains a source of concern.[100] One survey shows that intellectual property infringement is one of the major types of economic crime and it tends to result in big losses – over 30% of the relevant IP infringements imposed costs of more than 10 million USD on western European companies. In the chemicals industry, a typical incident of infringement happens when a business partner utilises technology obtained from another partner (*e.g.* through a joint venture) and often involves production processes and technologies (PwC (2008b), p.3).

107. In this respect, much attention has been directed to China (*e.g.* European Commission 2009b; US Department of Commerce, note 100). Despite efforts to strengthen its intellectual property rights

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[99] The Patent Act of 2005 contains an additional "improved efficacy" requirement for patentability of pharmaceuticals, which is being challenged by Novartis, following a patent rejection under this rule in 2006. The case was appealed to the Supreme Court in 2009. *See e.g.* Bate (2007).

[100] *See e.g. US Department of Commerce, Protecting Your Intellectual Property Rights (IPR) in China: A Practical Guide for U.S. Companies* <http://www.mac.doc.gov/China/Docs/businessguides/IntellectualPropertyRights.htm>.

enforcement since its accession to the WTO in 2001 and as technology transfer becomes more important for domestic companies, multinational companies operating in China attach high importance to further improvement of intellectual property protection. One survey shows that those multinationals often purposefully exclude vital parts or designs from processes in China, or strive to maintain a marketing reputation to make it difficult to replicate and undercut, and thus protect their intellectual property. Such strategies have proven relatively effective. On the other hand, protection through recourse to patent and trademark law or non-disclosure agreements with key employees are often used, but the survery shows that their effectiveness does not necessarily match expectations (von Keller *et al.* (2005), pp.26-27).

108. In the chemicals industry as well, multinationals have found it necessary to actively defend their intellectual properties in China (KPMG International (2009c), p.15). Many foreign investors take such precautions as creating firewalls between different steps of the production process, or refrain from sharing key technologies in a joint venture (PwC (2008b), p.12). These additional efforts to protect intellectual properties mitigate some of the potentially positive effects of statutory strengthening (*e.g.* on technology transfer) and divert resources away from innovative activities. The impact is particularly serious for smaller firms.

109. Finally, counterfeiting of chemical products can have serious consequences (*e.g.* HLG (2009), p.15). For example, counterfeit fertilisers and pesticides have caused vast damage to the environment, and they are often difficult to distinguish from legitimate products even for experts. Cases have been reported of the destruction of harvests in large areas in China, Russia, Ukraine and Italy due to the use of counterfeit chemicals. There are also concerns for health and safety (OECD (2008d), pp.138 and 148; ECPA (2008)).

5. Recent developments

110. Since the financial crisis in late 2008, the chemicals industry has been no exception in experiencing a decline in trade (-24.6%, 2009Q2)[101], although the rate of decline has been less than for the manufacturing sector as a whole (-29.9%). This sudden turn in economic fortune provoked fears of possible serious protectionist reactions, and against this background G20 leaders declared "within the next 12 months, we will refrain from raising new barriers to investment or to trade in goods and services, imposing new export restrictions, or implementing World Trade Organization (WTO) inconsistent measures to stimulate exports". [102] This was reaffirmed at subsequent summits in London and Pittsburgh in 2009.

111. Active monitoring activities of trade-related measures ensued, most notably at the WTO. It estimates that the value of total affected imports was 1% of the world trade (October 2008 – October 2009). WTO *et al*. (2010) notes "[i]n the period since September 2009, there has been continued slippage towards more trade-restricting and distorting policies by many G20 members, although there has been a slight slowdown in the number of measures implemented more recently compared with the period immediately after the outbreak of the global crisis" (p.20). In this general context, however, chemicals and plastics are among the industries most affected by recently introduced trade-related measures (Tables 9-10), comprising 8% of affected import value (other most affected industries include agricultural products, iron and steel, footwear, textiles and clothing, consumer electronics, and motor vehicles and parts). Out of 247 anti-dumping initiations between October 2008 and October 2009, metals have been the most targeted goods followed by chemicals (58) and plastics (30). A similar pattern is observed with countervailing duty investigations: out of 28 investigations initiated in 2009, 12 covered metals followed by plastics (4) and chemicals (3). In terms of safeguard, among 27 initiations in 2009, chemicals (7) was the most affected

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[101] The information in this and the following paragraphs is taken from WTO (2009b), except otherwise noted.

[102] *Declaration: Summit on Financial Markets and World Economy*, 15 November 2008, Washington.

sector, followed by cement/glass/ceramics (6). It is worth noting also that this sectoral pattern of protection is broadly consistent with the historical pattern.

112. On export measures, WTO (2010c) observes "an increasing trend in the use of export restrictions, affecting in particular food products and commodities", while acknowledging that a few countries also took measures to reduce the coverage of previously implemented export restrictions (para.46).[103]

113. These recent developments exemplify both values and limits to the existing multilateral trade disciplines. They have not stopped countries from taking these measures, but at the same time multilateral rules have shown resilience in this period of exceptional economic stress and maintained credibility as a multilateral "insurance policy" against the spread of protectionist reactions. This further underlines the importance of these monitoring activities to ensure transparency and to seek an ambitious and balanced conclusion of the Doha Development Round.[104]

Table 9. Trade and trade-related measures in the chemicals sector (October 2008-October 2009) [105]

Member	Measure	Status
Brazil	Initiation of anti-dumping investigation on imports of polypropylene from India, and the United States.	
China	Initiation of anti-dumping investigation on imports of adipic acid (HS 2917.12) from the EC, Korea, and the United States (10 November 2008).	Provisional measure imposed on 26 June 2009.
China	Initiation of anti-dumping investigation on imports of methyl-alcohol (HS 2905.11) from Indonesia, Malaysia, New Zealand, and Saudi Arabia (24 June 2009).	
China	Initiation of anti-dumping investigation on imports of polyamide-6 (HS 3908.10) from the EC, Chinese Taipei, Russia, and the United States (29 April 2009).	
China	Initiation of anti-dumping investigation on imports of polyamide-6,6 (HS 3908.10) from France, Italy, Chinese Taipei, United Kingdom, and the United States (14 November 2008).	Provisional measure imposed on 26 June.
China	Initiation of anti-dumping investigation on imports of terephthalic acid (HS 2917.36) from Korea and Thailand (12 February 2009).	
China	VAT rebate rates increased on exports of certain products including: iron and steel; non ferrous metals; petrochemicals; electronic and information technology products; and also some light industries such as textiles and clothing. None of these rebates exceed the current VAT rate of 17%.	
EC	Initiation of anti-dumping investigation on imports of certain polyethylene terephthalate (HS 3907.60.20) from Iran, Pakistan, and the United Arab Emirates.	
EC	Initiation of anti-dumping investigation on imports of dry sodium gluconate from China.	
EC	Initiation of anti-dumping investigation on imports of ironing boards, whether or not free standing, with or without a steam soaking and/or heating top and/or blowing top, including sleeve boards, and essential parts thereof (i.e. the legs, the top and the iron rest) (HS 3924; 4421;7323; 8516) from China.	
EC	Initiation of countervailing investigation on imports of certain polyethylene terephthalate (HS 3907.60.20) from Iran, Pakistan, and the United Arab Emirates.	

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[103] WTO *et al.* (2010, Table 2) reports several export measures applied by some G20 members, two of which are elimination of export duties and reduction of interim export duty rates on certain tariff lines including chemicals by China.

[104] *The G-20 Toronto Summit Declaration*, para.38, (26 – 27 June, 2010)

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[105] Excerpt from WTO (2009b), Annex 1. Trade facilitating measures (Annex 2), which mostly comprise termination or suspension of trade remedy initiations as well as a few instances of tariff reductions, are not listed in this table. Measures subsequently terminated, as listed in Annex 1 of WTO *et al.* (2010), are removed from the table.

Egypt	Revision of the tariff schedule for a number of products. Tariff decreases on the majority of them (for products such as raw materials, and intermediate goods). Tariff increases in products such as basic chemicals, bamboo manufacturing, rubber manufacturing, as well as certain basic machinery and medical equipment.	
India	Initiation of anti-dumping investigation on imports of acetone (HS 2914.11) from Japan and Thailand.	
India	Initiation of anti-dumping investigation on imports of coumarin (HS 2932.21) from China.	
India	Initiation of anti-dumping investigation on imports of phenol (HS 2707.60; 2907.11) from Japan and Thailand.	
India	Initiation of anti-dumping investigation on imports of phosphorous chemical compounds from China and the EC (13 February 2009).	
India	Initiation of countervailing investigation on imports of sodium nitrate from China.	
India	Initiation of safeguard investigation (China specific) on imports of soda ash (HS 2836.20).	Provisional measure imposed on 20 April 2009.
India	Initiation of safeguard investigation on imports of dimethoate technical (HS 3808.10).	Provisional and definitive measures imposed (until 22 March 2011).
India	Initiation of safeguard investigation on imports of phthalic anhydride (HS 2917.35).	Provisional and definitive measures imposed (until 31 December 2009).
Indonesia	Increase of import tariffs on 17 tariff lines such as: petrochemical, steel, and electronic parts.	
Morocco	Initiation of safeguard investigation on imports of PVC (HS 3904) (10 August 2009).	
Paraguay	Increase of import tariffs (10% and 15%) on certain chemical products.	
Peru	Initiation of countervailing investigation on imports of biodiesel from the United States.	
Russian Federation	New import tariffs on polyvinylchloride (15%), but not less than €0.12/kg (US$0.18/kg), for nine months.	Effective until 18 July 2010.
South Africa	Initiation of anti-dumping investigation on imports of tall oil fatty acid (HS 3823.13) from the United States (29 May 2009).	
Turkey	Initiation of safeguard investigation on imports of matches (HS 36.04; 36.05) (2 May 2009).	Provisional measure imposed.
Ukraine	Initiation of safeguard investigation on imports of liquid chlorine (HS 28.0110.0000).	
United States	Initiation of anti-dumping investigation on imports of commodity matchbooks (HS 3605.00) from India (24 November 2008).	Provisional measure imposed on 2 June 2009.
United States	Initiation of anti-dumping investigation on imports of polyethylene retail carrier bags (HS 3923.21) from Indonesia, Chinese Taipei, and Viet Nam (27 April 2009).	Preliminary determination in October 2009.
United States	Initiation of anti-dumping investigation on imports of sodium and potassium phosphate salts from China.	
United States	Initiation of countervailing duty investigation on commodity matchbooks (HS 3605.00) from India (24 November 2008).	Provisional measure imposed on 6 April 2009.
United States	Initiation of countervailing duty investigation on imports of polyethylene carrier bags (HS 3923.21) from Viet Nam (27 April 2009).	Preliminary determination in August 2009.
United States	Initiation of countervailing investigation on imports of sodium and potassium phosphate salts from China.	

Table 10. Trade and trade-related measures in the chemicals sector (September 2009 – February 2010) [106]

Member	Measure	Status
Argentina	Initiation of anti-dumping investigation on imports of methane chloride (NCM 2903.49.11) from China.	
Argentina	Introduction of non automatic import licensing requirements, covering products such as textile fabrics, autoparts, electrical machinery and equipments, vehicles, parts and accessories of the motor vehicles, articles of apparel and clothing accessories, chemicals, and paper	
China	Annual adjustment of the catalogue of items subject to automatic import licensing, which includes products such as pork, chicken, vegetable oil, tobacco, paper, milk, minerals, chemicals, electrical products, and certain steel products.	
EU	Initiation of anti-dumping investigation on imports of certain polyethylene terephthalate (HS 3907.60.20) from Iran, Pakistan, and the United Arab Emirates	
EU	Initiation of countervailing investigation on imports of certain polyethylene terephthalate (HS 3907.60.20) from Iran, Pakistan, and the United Arab Emirates.	
EU	Initiation of anti-dumping investigation on imports of ironing boards, whether or not free standing, with or without a steam soaking and/or heating top and/or blowing top, including sleeve boards, and essential parts thereof (i.e. the legs, the top and the iron rest) (HS 3924; 4421;7323; 8516) from China (Hardware).	
EU	Initiation of anti-dumping investigation on imports of purified terephthalic acid and its salts of a purity by weight of 99.5% or more (HS 2917.36.00) from Thailand.	
EU	Initiation of countervailing investigation on imports of purified terephthalic acid and its salts of a purity by weight of 99.5% or more (HS 2917.36.00) from Thailand.	
India	Initiation of anti-dumping investigation on imports of acetone (HS 2914.11) from Japan and Thailand.	
India	Initiation of safeguard investigation on imports of sodium hydroxide (caustic soda) (HS 2815.11; 2815.12).	Provisional measure imposed on 4 December 2009.
India	Initiation of anti-dumping investigation on imports of polymers of vinyl chloride or of other halogenated olefins in primary forms (HS 3904.22.10) from China; Japan; Korea; Malaysia; Russia; Chinese, Taipei; and Thailand.	
India	Initiation of anti-dumping investigation on imports of sodium tripoly phosphate (STPP) (HS 2835.31.00) from China.	
United States	Initiation of anti-dumping investigation on imports of certain sodium and potassium phosphate salts (HS 2835.24; 2835.31; 2835.39) from China (14 October 2009).	Partial affirmative preliminary injury determination and partial negative injury determination on 6 November 2009. Partial termination of investigation.
United States	Initiation of countervailing investigation on imports of certain sodium and potassium phosphate salts (HS 2835.24; 2835.31; 2835.39) from China (14 October 2009).	Partial affirmative preliminary injury determination and partial negative injury determination on 6 November 2009. Partial termination of investigation.

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[106] Excerpt from WTO *et al.* (2010), Annex 1. Trade facilitating measures, which comprise termination of trade remedy initiations as well as reductions of import and export duties, are not listed in this table. As a notable trade facilitating measures announced more recently, Canada will be eliminating MFN applied tariffs on “all manufacturing inputs and machinery and equipment”, including the chemicals. WTO, *Canadian Government Actions to Unilaterally Eliminate Certain Most-Favoured-Nation Applied Tariffs* (G/MA/W/101), 19 April 2010, submitted by Canada.

V. Conclusions

114. This study has highlighted the various linkages between trade and innovation in the chemicals sector. First, the transfer of advanced technologies, both as embodied in capital goods as well as through technology licensing, has been the key to the emergence of the chemicals industry as a global industry. In particular, the SEFs (specialised engineering firms) have played a unique role especially in basic industrial chemicals in technology spillovers, initially from the United States to Europe and to Japan and more recently to emerging economies.

115. Second, product innovation in the chemicals sector, especially in speciality and fine chemicals, contributes to innovation in downstream sectors, and trade serves as an essential conduit to transmit such innovations across borders.

116. Thirdly, as a consequence of wider availability of technologies across the globe, technology leaders in developed countries are under increasing competitive pressure from new competitors, which induces further innovation. The basic industrial chemicals sector has undergone continuous re-organisation with some companies now refocusing on speciality and fine chemicals. In speciality and fine chemicals, the product life cycle has been markedly shortened, and innovative capacity is an important factor in determining corporate performance in recent years.

117. Fourth, exports can also be important not just to exploit economies of scale, but foreign contacts can give suppliers innovative ideas, especially for speciality and fine chemicals and consumer chemicals. The increasing strength of emerging markets is a challenge but it is also offering opportunities for innovation.

118. Finally, joint ventures and cross border M&A also work as channels of technology transfer. China has been attracting foreign multinationals as partners in joint ventures in China, and Indian companies are active in acquiring chemical companies in the developed countries. At least part of the motivation is considered to be access to advanced technologies.

119. In terms of policy issues, this study has addressed tariff, regulation and intellectual property. Tariffs have declined substantially as a result of the Uruguay Round and autonomous tariff reductions, but remaining tariffs are still non-negligible and work as a trade impediment. Successful conclusion of the DDA negotiations is expected to play an important role in promoting trade liberalisation by bound tariff reduction. Export restrictive measures on raw materials are also an important concern in this sector, and proposals have been tabled to enhance transparency of these measures in the DDA negotiations.

120. The chemicals sector is a heavily regulated sector both domestically and internationally. Under WTO rules regulations may be considered legitimate if certain conditions are met. Many domestic regulations have been notified to the WTO according to the procedure provided in the TBT Agreement, and there have been over 1 600 notifications since 1995 in the chemicals sector. The impact of regulation on innovation can go either way, and it is likely to be specific to the regulatory design. Many major players in this sector have been pursuing regulatory initiatives to enhance data collection and to extend regulatory coverage to existing chemicals in recent years. Their practical impact remains to be seen, since they are still at an early stage of implementation or preparation. In relation to climate change issues, the chemicals sector is in a unique position as both a major sector in terms of energy use and CO2 emissions and as a major contributor to deliver solutions to climate change.

121. Intellectual property has particular importance in the chemicals sector because of the relative ease of producing chemicals as soon as the necessary technologies are known. Throughout the history of the chemicals industry, both patents and trade secrets have been used extensively depending on the nature of

technology and strategy. Patents have been instrumental in facilitating technology transfer by licensing. The practice of co-patenting is generally correlated with trade flows, indicating the possibility that trade relations work as a precursor to more long term collaborative innovation. Infringement of intellectual property continues to be a major problem that tends to incur high amount of losses to the intellectual property holders. Many multinational companies operating in China have taken various measures to protect their intellectual property, despite efforts to strengthen intellectual property rights enforcement by Chinese government.

122. Finally, as acknowledged at the OECD Council at Ministerial Level in 2007, to strengthen innovation performance and its contribution to growth, a strategic and comprehensive cross-government policy approach is required, and openness to trade is an essential element of the framework conditions that are necessary to stimulate innovation. The OECD Innovation Strategy (OECD, 2010a) is an important contribution to policymaking on broader aspects of innovation policy.

APPENDIX 1. TECHNICAL NOTES

All data contained in the graphs are compiled by the Secretariat for the purpose of this study, except otherwise indicated with the graph. Details of the data compiled by the Secretariat are as follows.

1. Trade Data

(1) All trade data are taken from the UN Comtrade in the World Integrated Trade Solution (WITS). Income groups are in accordance with the classification by the World Bank (2009), except that Chinese Taipei has been added to the high income group for the purpose of this study.

(2) For Figures 1–5, data are based on HS1996, supplemented by individual country data based on HS1992 for the year 1995 as well as for after 1996 where data based on HS1996 are unavailable in the database. While this procedure minimises the bias due to idiosyncrasies in underlying data coverage for each year, there still remain other biases. First, data in the WITS based on HS1996 are sometimes transposed from raw data in HS2002 or HS2007, depending on the availability of raw data. Second, transpositions between HS1992 to HS1996 (*e.g.* some transfer from Chapter 15 to Chapters 29 and 38), which can affect trade values by HS Chapter, are disregarded in the calculation. Third, this procedure does not necessarily ensure complete coverage of countries in the underlying data. For 2008, for example, data for some larger players such as Saudi Arabia were not yet available at the time of data compilation.

(3) Categorisation in Figure 6 is based on the Broad Economic Categories (BEC). In this classification system, majority of products under HS Chapters 28-39 are categorised into "industrial supplies n.e.s. (2)", "consumer goods n.e.s. (6)", while some are "food and beverages (1)" and "fuels and lubricants (3)" which are referred to as "others" in Figure 8. All these except consumer goods are categorised as intermediate goods for the purpose of national accounts (*see* United Nations (2002), pp.5-6).

2. Tariff Data

(1) All data are taken from the UNCTAD/TRAINS supplemented by the WTO/IDB, in order to maximise the underlying data coverage.

(2) "Simple average" in Figures 7 and 8 means simple average of the simple average tariff rates for a product group across countries in a group. "Weighted average" in Figure 7 means weighted average (by import value) of weighted average tariff rates for a product group across countries in a group.

(3) "CTHA" covers original participants to the agreement (Canada, EU (27), Japan, Korea, Norway, Singapore, Switzerland, United States), "New WTO" covers those acceded to the WTO after 1995 except LDCs, Tonga and new EU member states (Albania, Armenia, China, Croatia, Ecuador, FYR Macedonia, Georgia, Jordan, Kyrgyz Republic, Moldova, Mongolia, Oman, Panama, Saudi Arabia, Chinese Taipei, Ukraine, Vietnam), "Non-CTHA" covers those not considered as having participated to the CTHA and larger traders in chemicals (top 15 traders among non-participants in 2008, except Belarus and Russia due to insufficient data availability) (Argentina, Brazil, Colombia, Egypt, India, Indonesia, Israel, Malaysia, Mexico, Philippines, South Africa, Thailand, Venezuela). These categorisations are made in reference to the information from the European Commission <http://ec.europa.eu/enterprise/sectors/chemicals/competitiveness/international-activities/trade_en.htm >

and USTR <http://www.ustr.gov/trade-topics/industry-manufacturing/industry-initiatives> websites. For Table 2, "Other OECD" consists of Australia, Iceland, New Zealand and Turkey. They are not original CHTA participants but are considered *de facto* in line with CHTA commitment (European Commission website above).

3. R&D Intensity, Patent

(1) R&D expenditures, production values and patent data are taken from OECD STAN Database for Structural Analysis, the STAN R&D Expenditure in Industry (ISIC Rev. 3) ANBERD ed2009, and OECD Patent Database.

(2) Patent data represent the number of patent applications under Patent Cooperation Treaty (PCT). "Chemistry" in Figure 13 refers to technology areas C01-C14 in International Patent Classification (IPC), and "Metallurgy" refers to the rest of Section C. Although PCT applications facilitate international comparison of patent statistics, the period up to 2000 is a transition period that needs to be interpreted with care (OECD (2009a), p.66).

(3) Technology classifications in Figures 14-15 are in reference to "new concept of technology classification" in Schmoch (2008), p.9.

APPENDIX 2. TRADE PATTERNS AND CO-INVENTION

a) The Model

To test the impact of tariffs and patent application on trade flows, the estimation has been based on the gravity model with fixed effects after Anderson and van Wincoop (2003) adapted in Portugal-Perez *et al.* (2009). The specification here is:

$$\ln(\text{import})_{ijt} = \ln(1 + \text{tariff rates})_{ijt} + \ln(\text{patent, importer})_{it} + \ln(\text{patent, exporter})_{jt} + \ln(\text{patent, co-invention})_{ijt} + D_{ij} + x_i + y_j + (w_t) + e_{ijt}$$

For importer i, exporter j and year t, with fixed effects in the importer (x), exporter (y) and product (w) dimensions. D covers distance, common language dummy and contiguous (common border) dummy. The estimation is done with respect to three sub-sectors.

Portugal-Perez *et al*. (2009) tested the impact of international standards and tariffs on trade flows with similar control variables, but patent applications may also be associated with trade flows. If patent applications represent export competitiveness, exporters' patent application should have positive signs, and if patent applications reflect absorptive capacity of foreign technology, importers' patent application should have positive signs. If cross-border co-invention (patent applications filed with foreign inventors) represents global collaborative networks which cover both technological exchanges and trade in goods, it should have a positive sign. Causation between co-invention and trade flows can further be tested by changing the timing of co-invention (one-year lag and one-year lead) in the estimation.

(b) Data

Variables	Source and definition	Coverage
Imports	UN Comtrade in WITS. Gross import in thousand USD by HS Chapters (29-39) in HS 1996.	66 larger importers in chemicals (HS28-39) in 2008 (and 2007), of which 30 are OECD members.
Tariff	UNCTAD/TRAINS supplemented by WTO/IDB, both in WITS. Simple average of effective applied tariffs (AHS) by HS Chapters (28-39) in HS 1996. Tariff rates for EU Member States are set as the common external tariff, and tariff rates among EU Member States are set to zero.	
Patent	OECD patent database (2000-2006) for No.14 and 17 in technology classification update of 2008. "Patent" is the number of patent applications, and "co-invention" is the number of patent applications done with at least one foreign co-inventor from a specified country.	31 OECD members and 18 non-members for total patent counts and co-patenting with Belgium, Canada, China, France, Germany, Ireland, Italy, Japan, Korea, Netherlands, Switzerland, United Kingdom and United States.
Distance, Contiguous, Common Language	CEPII dataset. "Distance" is weighted by the geographic distribution of population, common language is set one if a language is spoken by at least 9% of the population in both countries	

While the technology classification for patens and HS classification for trade do not match precisely, following correspondence is assumed for the purpose of this estimation. Note also that distinction between process patent and product patent is not possible using this data.

Technology classification	IPC Code	HS Chapter
14 Organic fine chemistry	C07 Organic Chemistry (except C07G,K,M)	29 Organic chemicals
17 Macromolecular chemistry, polymers	C08 Organic Macromolecular Compounds; Their Preparation or Chemical Working-up; Compositions Based Thereon (except C08J)	39 Plastics and articles thereof
19 Basic materials chemistry	C05 Fertilisers, Manufacture thereof C06 Explosives, Matches C09 Dyes; Paints; Polishes; Natural Resins; Adhesives; Compositions not otherwise Provided for; Applications of Materials not otherwise Provided for C10 Petroleum, Gas or Coke Industries; Technical Gases Containing Carbon Monoxide; Fuels; Lubricants; Peat C11 Animal or Vegetable Oils, Fats, Fatty Substances or Waxes; Fatty Acids Therefrom; Detergents; Candles	31 Fertilisers 32 Dyes, paints 33 Perfumery, cosmetics 34 Soap, detergents 35 Glues, adhesives 36 Explosives 37 Photographic goods 38 Misclaneous 39 Plastics

(c) Results (imports (dependent variable), tariff patent and co-invention in the table are in natural logarithm)

(i) Organic (Fine) Chemicals (years 2000-2006)

	Base	Co-invention	Co-inv.(lag)	Co-invention (lead)
Tariff	-1.433311 b (0.6321134)	-4.734834 a (1.276256)	-4.732052 a (1.203096)	-4.899747 a (1.376141)
Patent, Importer		-0.1017004 (0.0968362)	-0.0695776 (0.091075)	-0.1988894 c (0.110456)
Patent, Exporter		0.2100398 (0.1408937)	0.1879851 (0.1543011)	0.0900832 (0.1729524)
Co-invention		0.2100398 a (0.0300893)	0.098426 a (0.0347416)	0.0515396 (0.0377196)
Co-invention (lag)			0.0484925 (0.034474)	
Co-invention (lead)				0.1102481 a (0.0337251)
Distance	-1.265295 a (0.0216698)	-0.7555046 a (0.0370925)	-0.658346 a (0.0435392)	-0.6322955 a (0.0457142)
Common Border	0.9846807 a (0.0657511)	0.142995 c (0.0868083)	0.3010695 a (0.1000616)	0.3147538 a (0.0990153)
Common Language	0.5253304 a (0.0470272)	-0.0209336 (0.0691743)	-0.1451685 b (0.0700912)	-0.1768056 b (0.0697392)
N	20029	1287	772	772
R2	0.9570	0.9970	0.9984	0.9984

(ii) Macromolecular Chemistry/Plastics (years 2000-2006)

	Base	Co-invention	Co-inv. (lag)	Co-inv. (lead)
Tariff	-4.038687 a (0.4071758)	-8.605403 a (1.03745)	-11.72978 a (1.578569)	-10.71352 a (1.584395)
Patent, Importer		-0.1146458 (0.0746657)	-0.3490482 a (0.1118286)	-0.2484919 b (0.1100306)
Patent, Exporter		0.0860082 (0.1476102)	-0.1034204 (0.1574743)	-0.0275452 (0.159763)
Co-invention		0.0846799 a (0.0265775)	0.074038 b (0.0363854)	0.0839119 b (0.0399827)
Co-invention (lag)			0.0610926 (0.0377349)	
Co-invention (lead)				0.0448823 (0.0356383)
Distance	-1.723183 a (0.02097)	-0.881258 a (0.0352096)	-0.8253184 a (0.0425278)	-0.8239965 a (0.0438597)
Common Border	0.6358035 a (0.0650711)	0.4848155 a (0.0757988)	0.5502438 a (0.0768031)	0.563554 a (0.0799174)
Common Language	0.8100924 a (0.0420215)	0.0676071 (0.0604088)	-0.0337372 (0.0695726)	-0.0178872 (0.0697031)
N	22698	1155	703	703
R2	0.9671	0.9983	0.9987	0.9987

(iii) Basic materials Chemistry (years 2000-2006)

	Base	Co-patent	Co-inv. (lag)	Co-inv. (lead)
Tariff	-3.010211 a (0.448264)	-5.66043 a (0.8224381)	-6.767096 a (1.085467)	-6.651567 a (1.16718)
Patent, Importer		0.0029086 (0.0718667)	-0.1141443 (0.0760867)	-0.2444847 a (0.0879158)
Patent, Exporter		0.2738578 a (0.104339)	0.4482073 a (0.1274934)	0.3701484 a (0.1276349)
Co-invention		0.0500766 b (0.0213988)	0.0881613 a (0.0250844)	0.0716266 a (0.0247512)
Co-invention (lag)			0.0768807 a (0.0248798)	
Co-invention (lead)				0.0907757 a (0.0242817)
Distance	-1.525685 a (0.0192335)	-0.8097943 a (0.024473)	-0.7463699 a (0.0296804)	-0.725066 a (0.0303864)
Common Border	0.5532178 a (0.0571751)	0.2670372 a (0.0554316)	0.2226323 a (0.060364)	0.2914813 a (0.0612816)
Common Language	0.6379643 a (0.0391108)	0.0741463 (0.0466079)	0.074473 (0.0532775)	0.0467913 (0.0467913)
N	23047	1212	745	745
R2	0.9673	0.9989	0.9993	0.9993

Note: Robust standard errors in the parentheses; a, b and c in the table shows the levels of statistical significance (a: $p<0.01$, b: $0.01<p<0.05$, c: $0.05<p<0.10$)

(d) Observations

Co-invention is significantly and positively correlated to trade flows. Co-invention with one-year lag is statistically significant only for basic materials chemistry, but not for others. Co-invention with one-year lead is statistically significant for organic chemistry and for basic materials chemistry, but not for macromolecular chemistry. In both "lag" and "lead", signs are invariably positive. Therefore it appears that this positive causation between the two is different in different sub-sectors: in organic chemistry bilateral trade relations foster bilateral co-invention; in macromolecular chemistry both relations are contemporaneous; and in basic materials chemistry they are mutually reinforcing. But in practice, when collaborative activities leading up to joint patent application is taken into account, such efforts may have a positive implication in fostering trade relations.

The results point to strong relationship between cross border collaborative networks and trade flows within each technology areas, but it does not capture such relationship across different industrial segments.

Exporters' patent application is generally positively correlated with trade flows, but statistically significant only for basic materials. Importers' patent application is generally negatively correlated with trade flows, but statistical significance varies (statistically significant when estimated with "co-patent (lead)").

Negative impact of tariffs is statistically significant[107], and the signs of other control variables (distance, language and contiguity) are also as expected. The levels of coefficients vary considerably across different sub-sectors.

(e) References

OECD (2009), *OECD Patent Statistics Manual*, Chapters 5 and 7.

Portugal-Perez, Alberto, José-Daniel Reyers and John S. Wilson, "Beyond the Information Technology Agreement: Harmonization of Standards and Trade in Electronics", *Policy Research Working Papers* 4916, The World Bank Development Research Group, Trade Team, April 2009.

Schmoch, Ulrich, Francoise Laville, Pari Patel and Rainer Frietsch (2003), *Linking Technology Areaas to Industrial Sectors: Final Report to the European Commission, DG Research*, November 2003. < ftp://ftp.cordis.europa.eu/pub/indicators/docs/ind_report_isi_ost_spru.pdf >

Schmoch, Ulrich (2008), *Concept of a Technology Classification for Country Comparisons: Final Report to the World Intellectual Property Organisation (WIPO)*, Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, Germany, June 2008. <http://www.wipo.int/export/sites/www/ipstats/en/statistics/patents/pdf/wipo_ipc_technology.pdf>

World Intellectual Property Organisaion (WIPO), *International Patent Classification (IPC)* < http://www.wipo.int/classifications/ipc/en/>

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[107] As the tariff in this estimation is in logarithm, the coefficient is similar to price elasticity of trade flows. With the estimation based on tariff in percentage points, the coefficients are 0.014-0.040 for organic, 0.030-0.098 for plastics and 0.021-0.059 for basic materials, or one percentage point increase in applied tariff is associated with 1.4-9.8 percent decrease in imports.

APPENDIX 3. TRADE, TARIFFS AND R&D

(a) The Setup

To consider the relations between trade, tariff and R&D across countries, variables are all constructed in comparative terms:

- $EXPORT_a = (x_{as}/x_a)/(X_s/X)$ (*i.e.* revealed comparative advantage (RCA))
- $IMPORT_a = (m_{as}/m_a)(M_s/M)$
- $R\&D_a = (r_{as}/r_a)/(R_s/R)$
- $TARIFF_a = (t_{as}/t_a)/(T_s /T)$

X, M and R are OECD total of exports, imports and R&D spending, T is OECD average tariff, x_a, m_a and r_a are exports, imports and R&D spending and t is the average tariff for country a, all with respect to year t (subscript suppressed above). Subscript s shows the industrial sector.

With these variables, two types of estimation are carried out:

(i) R&D and Trade

- $EXPORT_{ast} = R\&D_{ast} + w_t + x_a + z_s$
- $IMPORT_{ast} = R\&D_{ast} + w_t + x_a + z_s$

(ii) Trade, R&D and Protection

- $TARIFF_{ast} = EXPORT_{ast} + IMPORT_{ast} + R\&D_{ast} + w_t + x_a + z_s$

And w, x and z are time, country and sector dummies.

(b) Data

Variable	Source	Coverage
Exports, Imports	STAN database	OECD members except Chile, Mexico and Luxembourg (and other occasional data omissions due to data availability).
R&D spending	STAN database	As above plus Chile, China, Israel, Romania, Russia, Singapore, Slovenia, Chinese Taipei and South Africa.
Tariff	TRAINS, IDB	Simple average effective applied tariffs.
Industrial sector	ISIC Rev.3: 15-16, 17-19, 20, 21-22, 23-25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35	
EU	EU Member States are treated separately for "R&D and Trade" and (2), and EU is treated as one in "Trade, R&D and Protection". In latter case exports, imports and R&D spending are aggregated for the EU, and community tariff is used.	

(c) Results

(i) R&D and Trade

Dependent variable: EXPORT

	Years 1995-2000		Years 2001-2006	
	Chemicals	All Manufacture	Chemicals	All Manufacture
R&D	.2173662 b (.0888008)	.2584787 a (.0526775)	-.0004321 (.0196937)	. 3055779 a (.0315001)
N	148	2228	146	2231
R2	0.9872	0.6499	0.9957	0. 6685

Dependent variable: IMPORT

	Chemicals	All Manufacture	Chemicals	All Manufacture
R&D	.1549626 b (.0647578)	. 0066426 c (.0039599)	-.0134601 (.02293)	. 0195038 b (.0097155)
N	148	2228	146	2231
R2	0.9976	0.8827	0.9977	0.7859

(ii) Trade, R&D and Protection

(ii)-1 Chemicals (except pharmaceuticals), for years 1995-2000 and 2001-2006

Dependent variable: TARIFF

1995-00	1	2	3	4	5
EXPORT		.7117542 (.4637047)		.4836218 (.9187352)	.2208916 (.9488631)
IMPORT			.6683983 b (.3131411)		.4099335 (.4781415)
R&D	.455049 b (.2140794)			.3159617 (.3825776)	.2921251 (.3884123)
N	73	75	75	64	64
R2	0.9746	0.9715	0.9716	0.9716	0.9719

2001-06	1	2	3	4	5
EXPORT		-.0158441 (.202788)		-.2170463 (.4744383)	-.4602971 (.5330931)
IMPORT			.434769 c (.2455852)		.9783517 b (.4733983)
R&D	-.0530082 (.1264313)			-.0869141 (.1332447)	-.102631 (.0969616)
N	66	70	70	55	55
R2	0.9887	0.9880	0.9886	0.9889	0.9899

(ii)-2 All Manufacturing, for years 1995-2000 and 2001-2006

Dependent variable: TARIFF

1995-00	1	2	3	4	5
EXPORT		-.0700267 a (.0107712)		-.0609264 a (.01551)	-.0632281 a (.0158259)
IMPORT			.0167866 (.0302361)		.0500804 (.0320144)
R&D	-.025651 a (.0069923)			-.0067371 (.0094186)	-.0061103 (.0095861)
N	1123	1200	1200	972	972
R2	0.8411	0.8304	0.8246	0.8371	0.8375

2001-06	1	2	3	4	5
EXPORT		-.0547584 a (.0099709)		-.0672083 a (.0155499)	-.0704434 a (.0157249)
IMPORT			. 029072 (.0337097)		.0615276 (.0382517)
R&D	-.0542115 b (.0260584)			. 0176896 (.0132536)	. 0187046 (.0133304)
N	1117	1107	1107	853	853
R2	0.5947	0.7569	0.7530	0. 7616	0.7624

Note: Robust standard errors in the parentheses; a, b and c in the table shows the levels of statistical significance (a: $p<0.01$, b: $0.01<p<0.05$, c: $0.05<p<0.10$)

(d) Observations

(i) R&D and Trade

R&D is positively associated with exports in all manufacturing sectors, both in the 1990s and 2000s. It was the case with chemicals, but it is not statistically significant in the 2000s.

R&D is positively associated with imports in all manufacturing sectors in both periods, but the impact is much smaller than with exports. It was positively associated in chemicals in 1990s but not any longer in 2000s.

Other factors than R&D within the chemicals sector may have become more important for comparative advantage of the chemicals in 2000s. For example, introduction of the fruits of R&D generated by other industries and/or from abroad through technology licensing or imports of superior capital goods or intermediate goods, rather than domestic R&D within the sector, may have become more important.

(ii) Trade, R&D and Protection

R&D and exports are both negatively associated with tariff levels in all manufacturing sectors. In other words, comparative advantage and the underlying R&D capacity are associated with lower tariff levels. But if both of them are controlled, R&D tends to lose statistical significance.

In chemicals in 1990s, the signs for R&D and exports were both positive, but they turned negative in the 2000s, but without statistical significance.

Imports have no statistically significant association with tariff levels in all manufacturing sectors. Imports tended to have positive association with tariff levels in chemicals.

Positive association between R&D and tariffs may imply a policy to compliment lesser R&D capacity by imports, and negative association may imply a policy to protect sectors with lesser R&D capacity. But from this simple test of association, clear evidence does not emerge in either direction.

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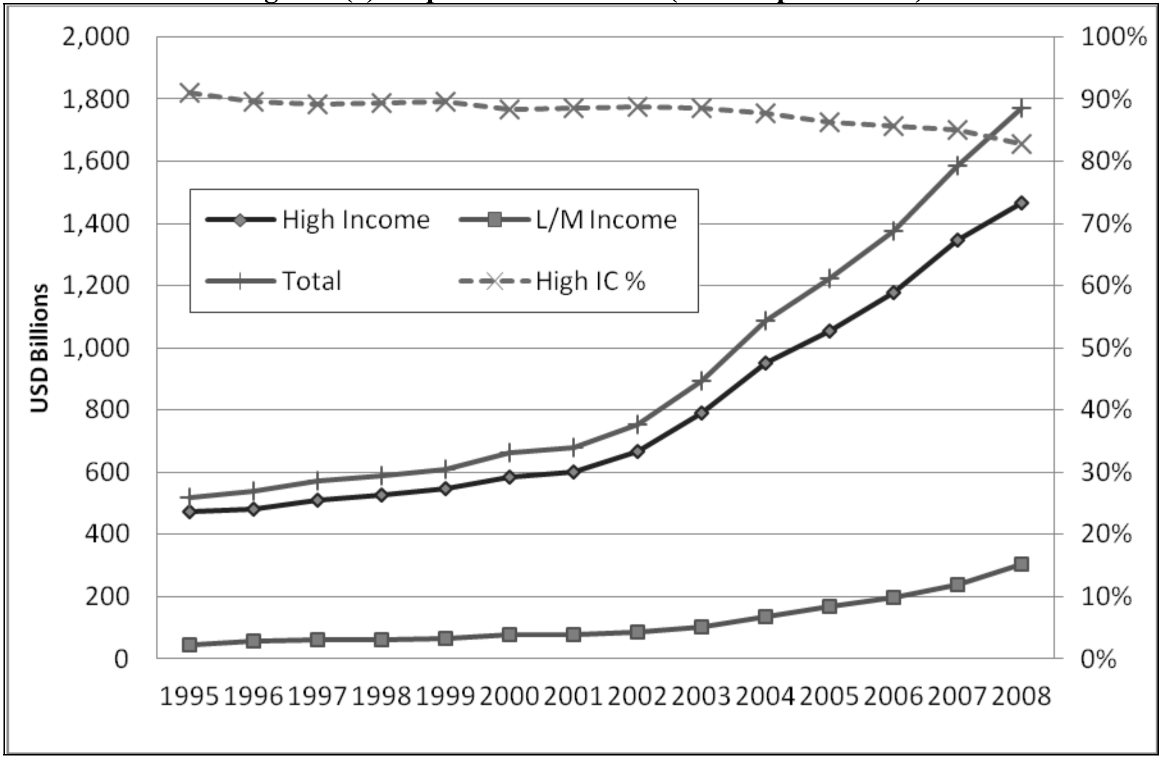
Figure 1(a). Exports of Chemicals (HS Chapters 28-39)



Note: See Appendix 1 for detailed description of the data and the sources.

Figure 1(b). Imports of Chemicals (HS Chapters 28-39)

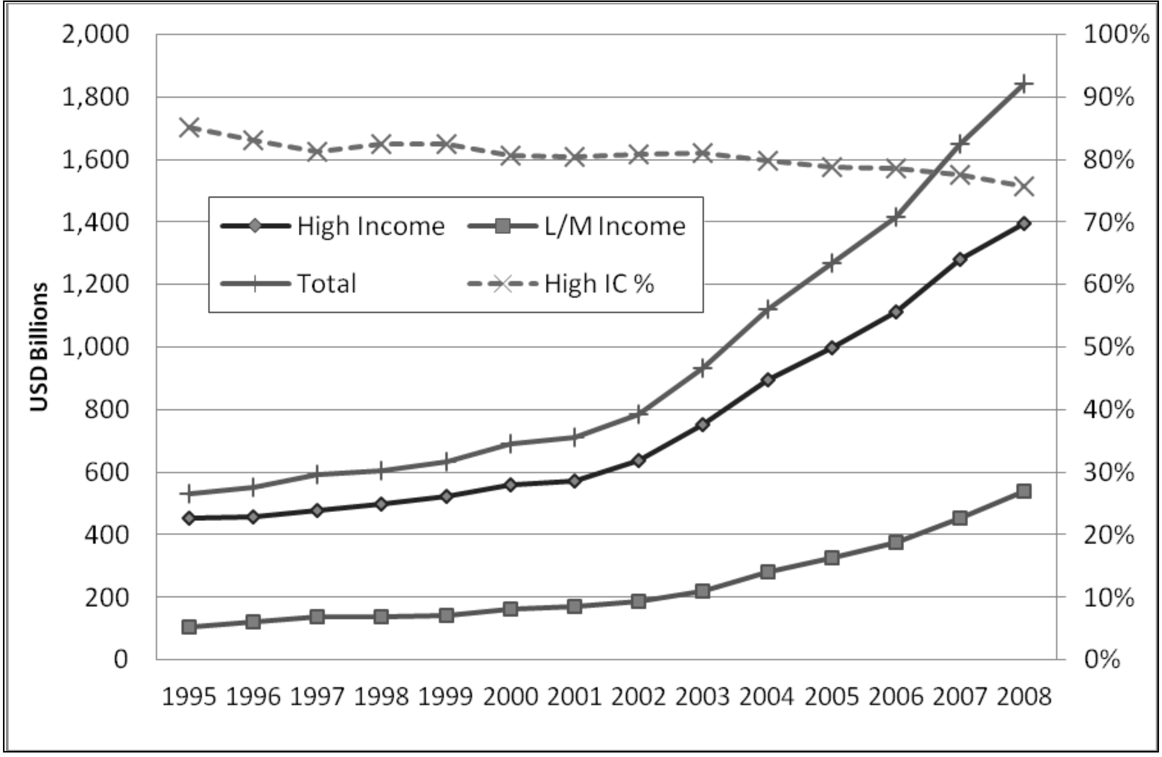


Figure 2(a). Annual Export Growth and % Share in Total Merchandise Trade

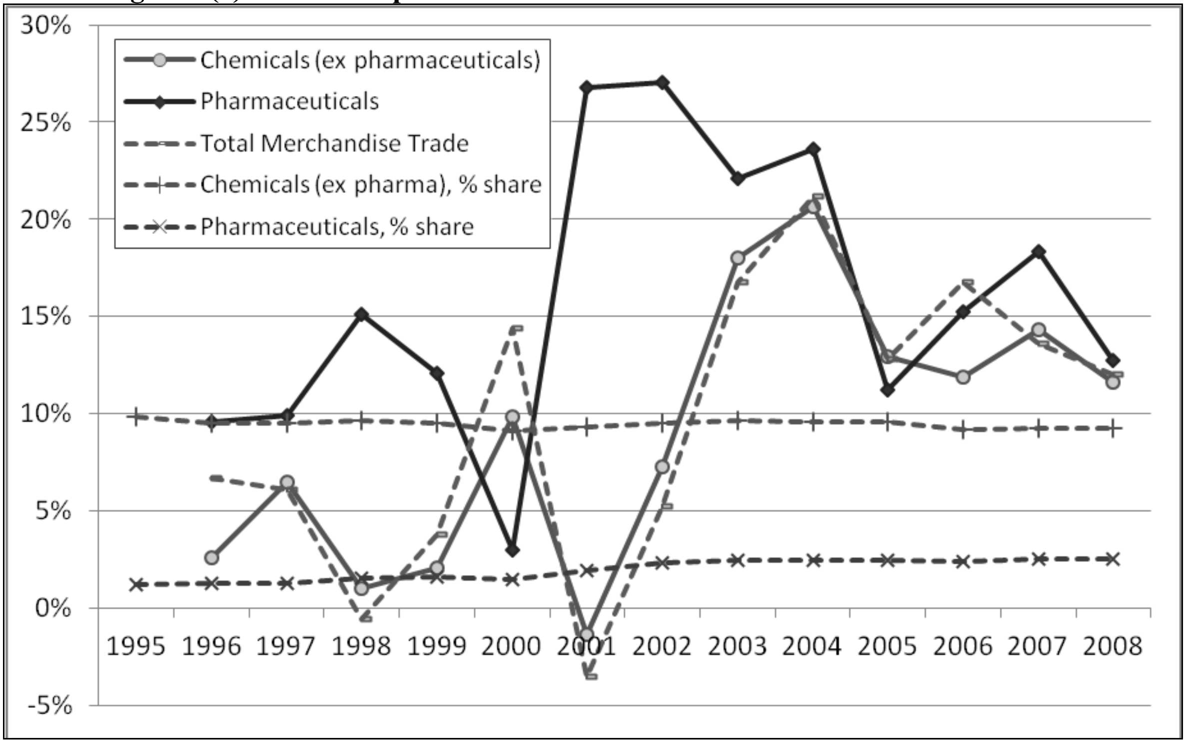


Figure 2(b). Export Growth by HS Chapter
(Bar chart: 1990s v. 2000s; Line chart: High v. Low and Middle Income in 1995-2008)

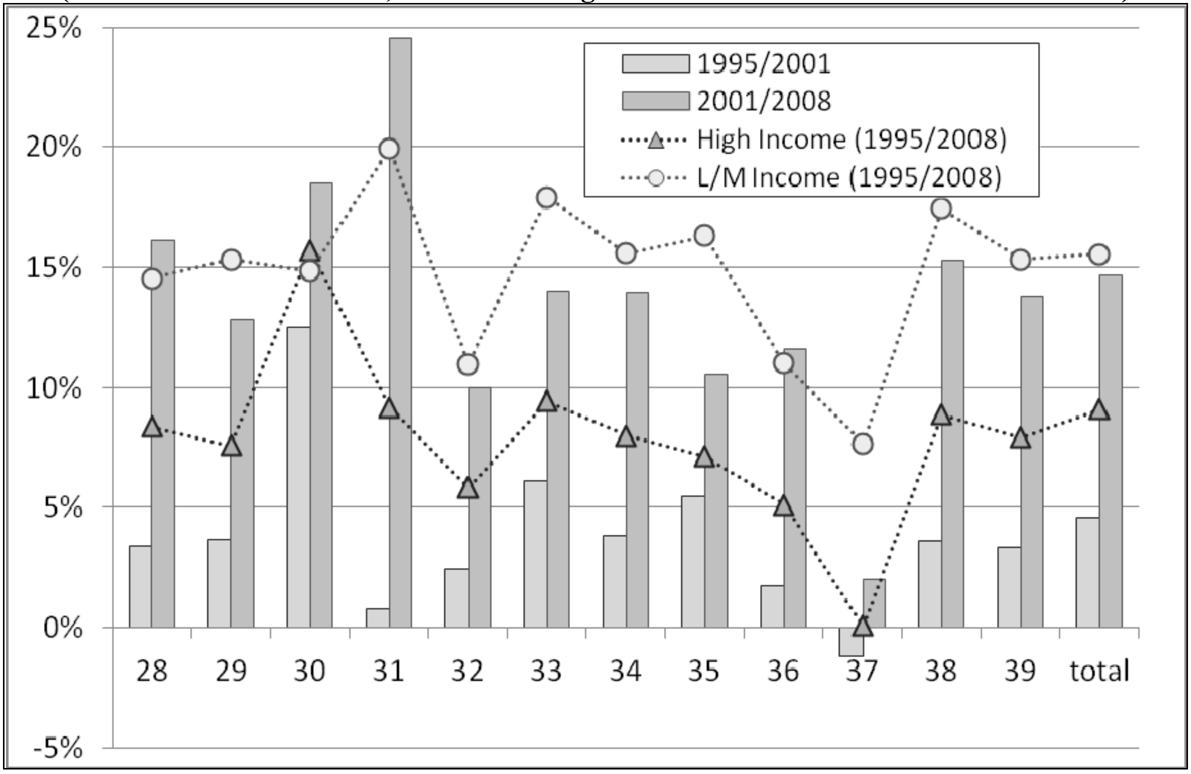


Figure 3(a). Export Composition by HS Chapter (1995 v. 2008, by Income Group)

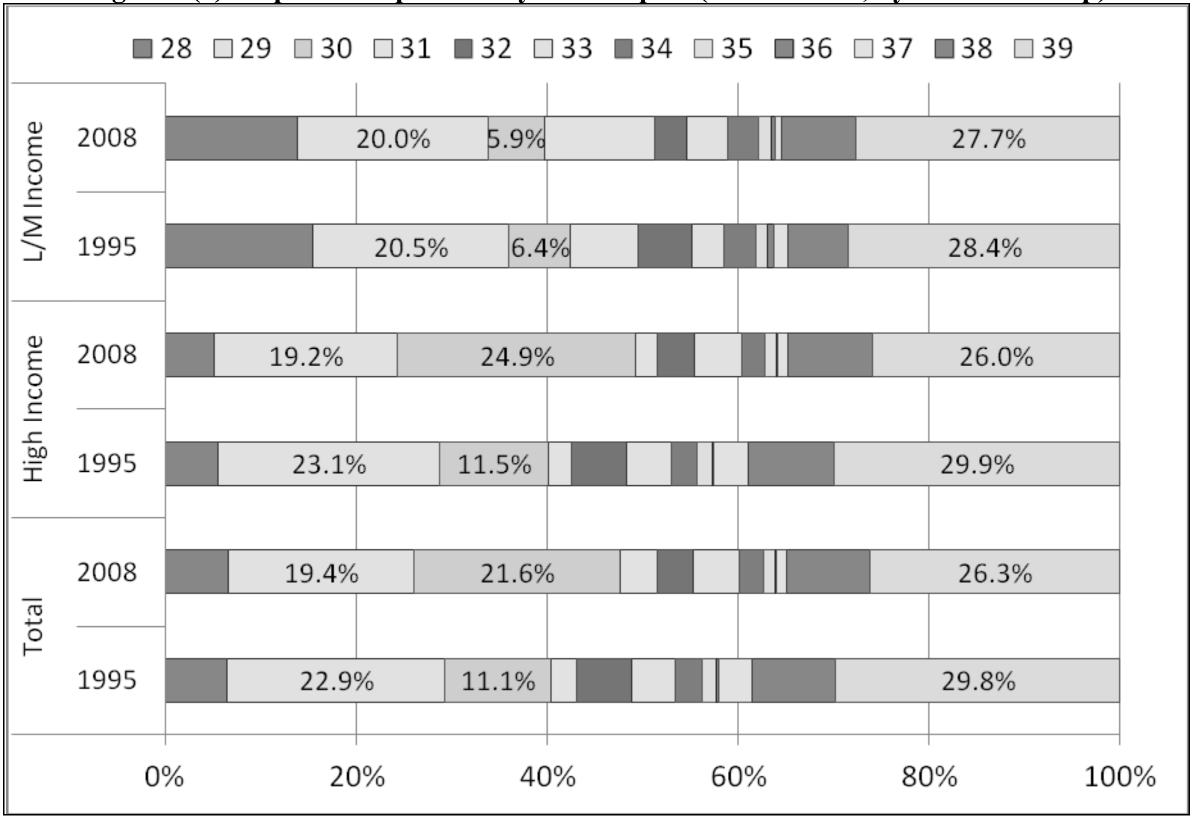


Figure 3(b). Import Composition by HS Chapter (1995 v. 2008, by Income Group)

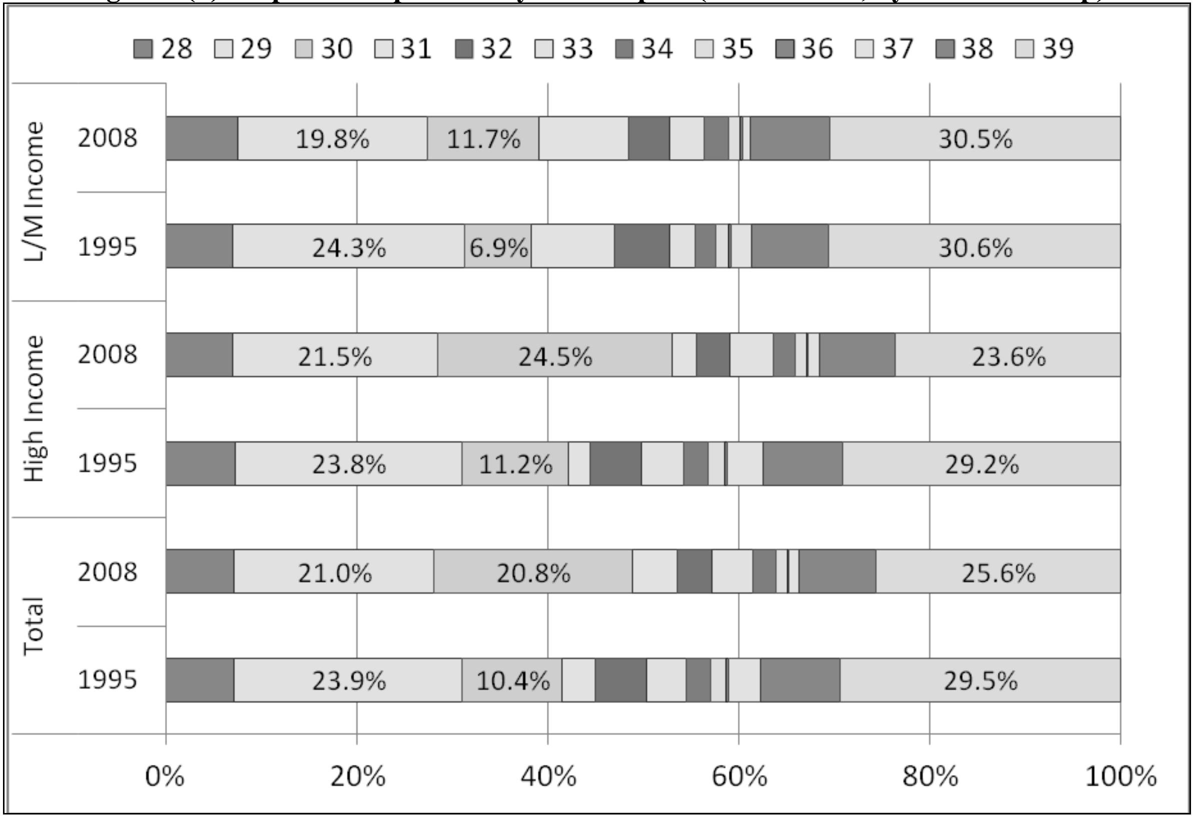


Figure 4(a). Exports of Chemicals by Income Group Pair

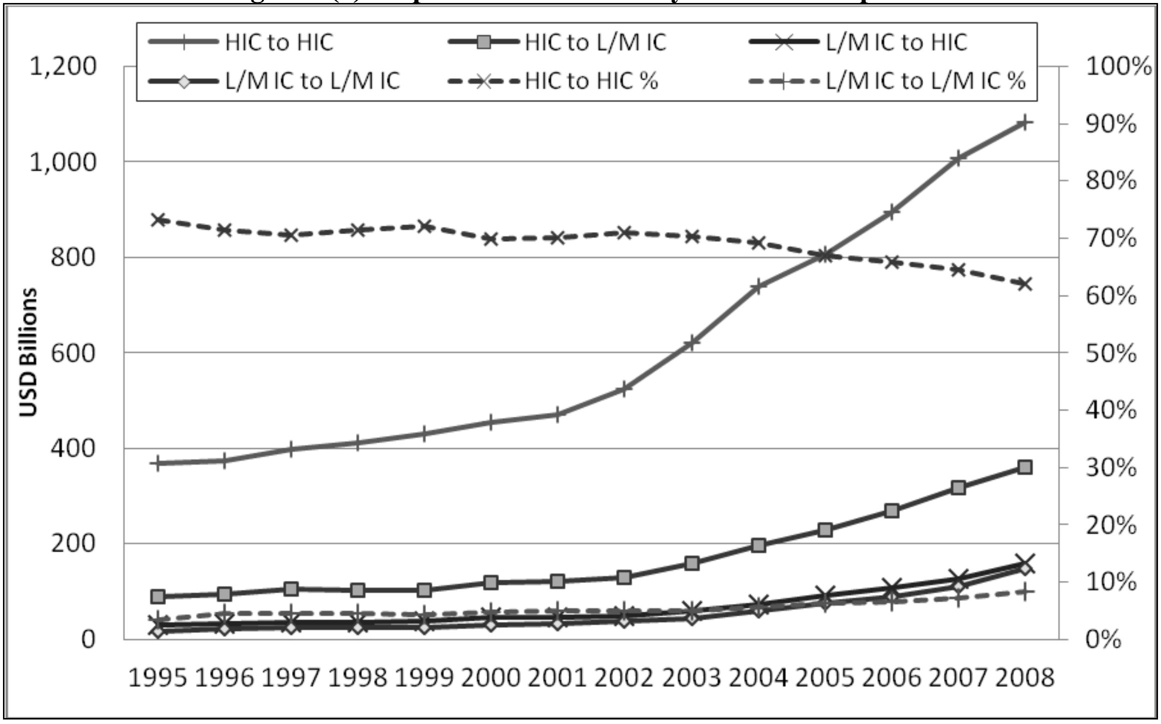


Figure 4(b). Export Growth of Chemicals by Income Group Pair (2001-2008)
(Bar chart: % share of additional export value by HS Chapters in an income group pair;
Line chart: Growth rates by HS Chapter and income group pair)

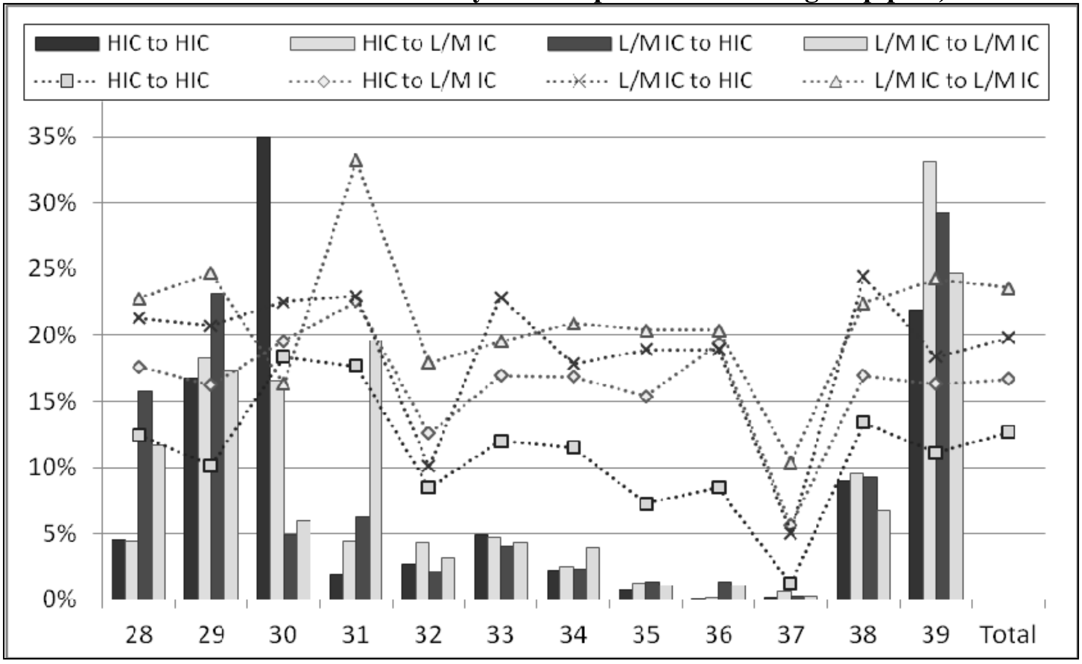


Figure 5(a). Major Exporters (export values in 1995, 2001and 2008, and growth rates)

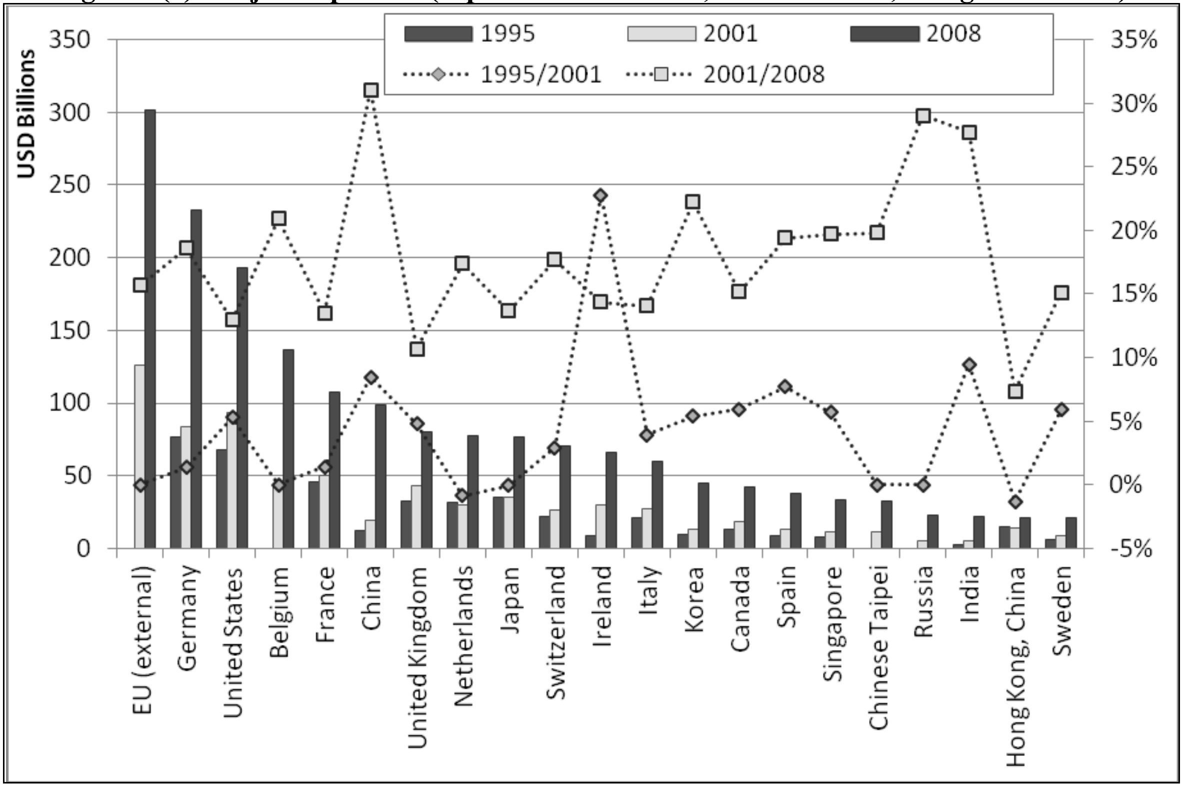
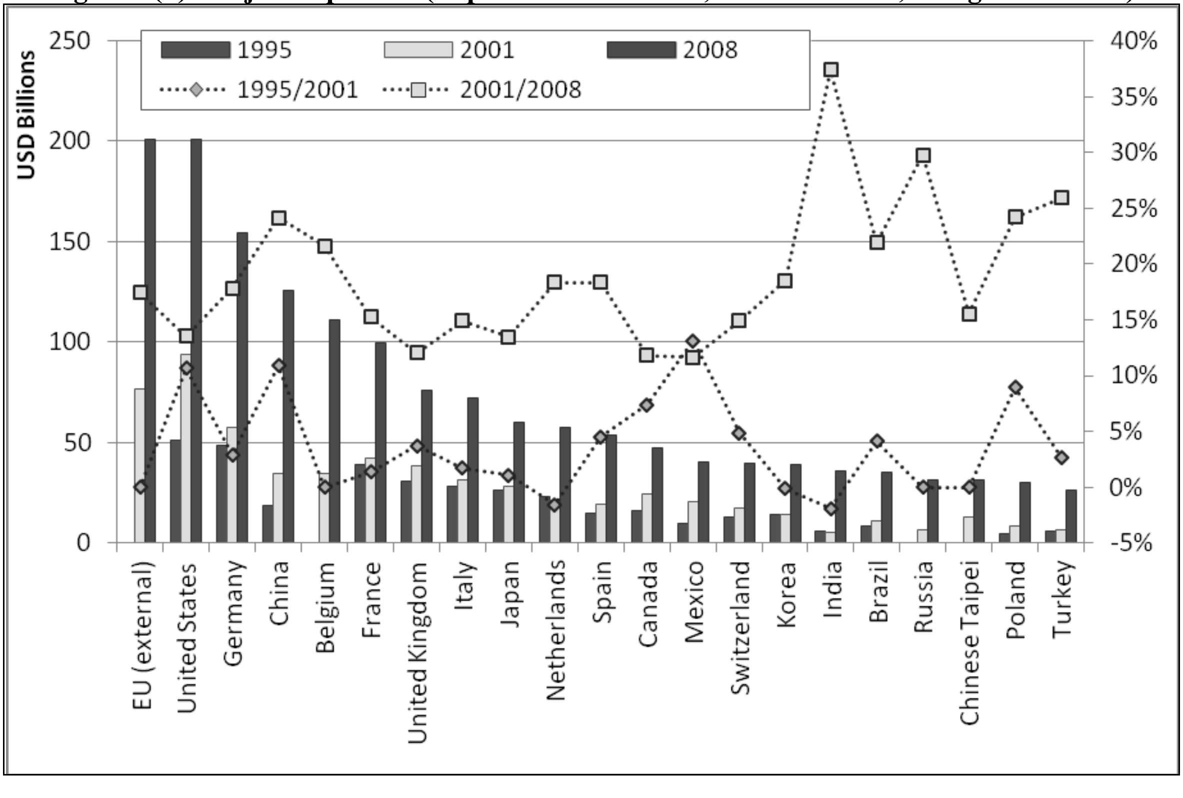


Figure 5(b). Major Importers (import values in 1995, 2001 and 2008, and growth rates)



Note: Data for 1995 is replaced by 1997 for Chinese Taipei and 1996 for Russia due to data availability.

Figure 6(a). Export Composition by End Use (BEC (Broad Economic Categories))

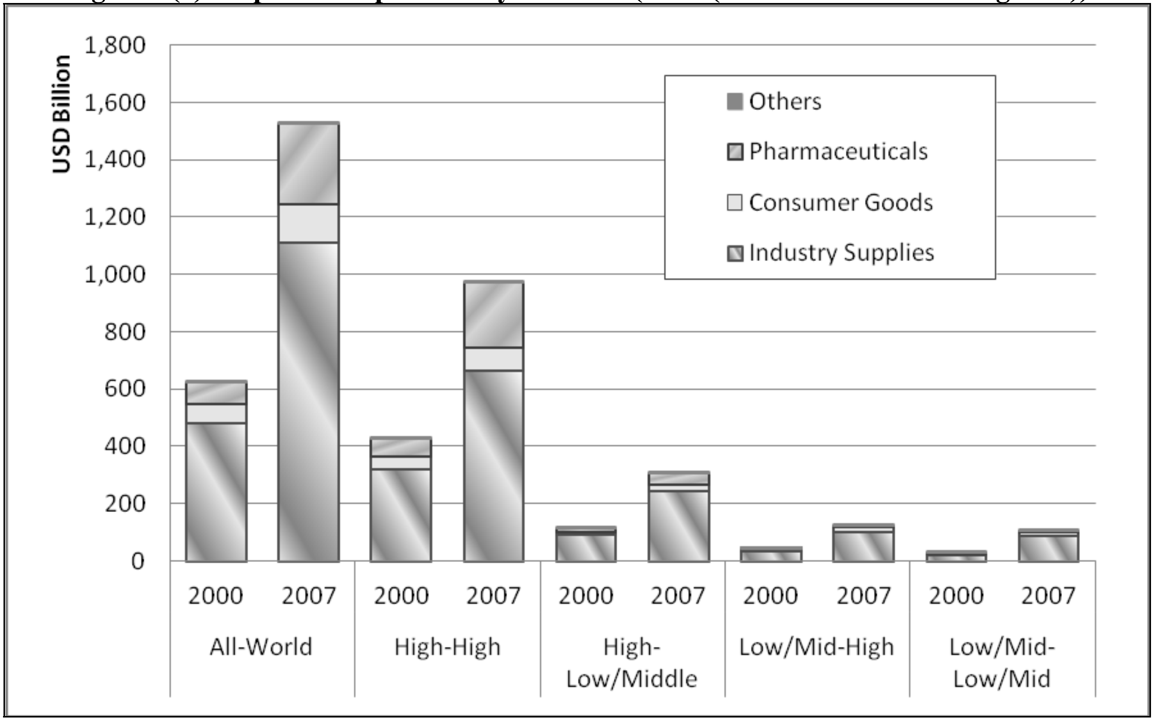


Figure 6(b). Export Composition by End Use (BEC; legends as in (a))

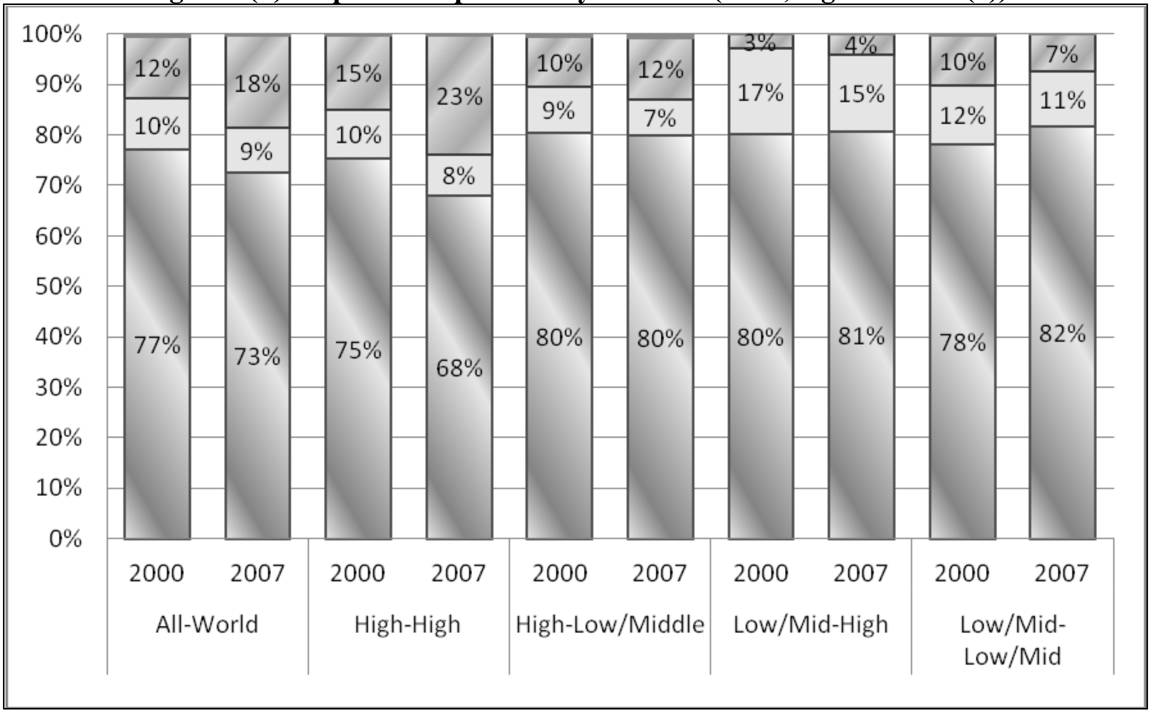


Figure 7(a) MFN Applied Tariffs on Chemicals

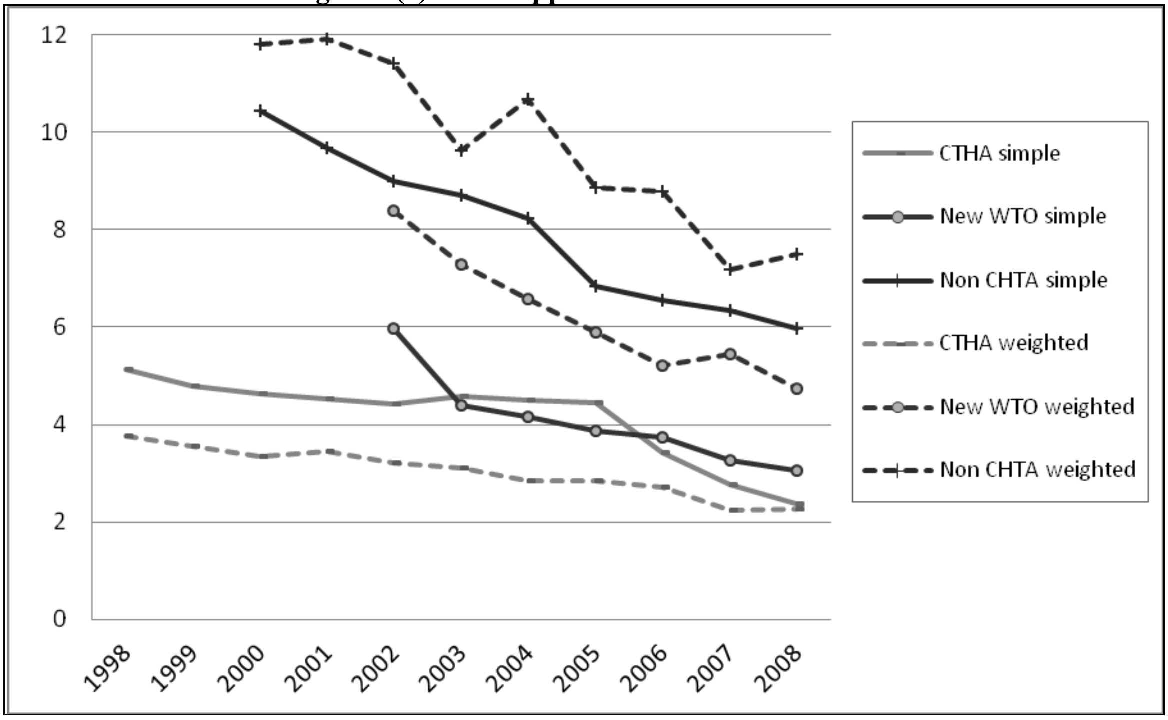


Figure 7(b) Bound Tariffs on Chemicals

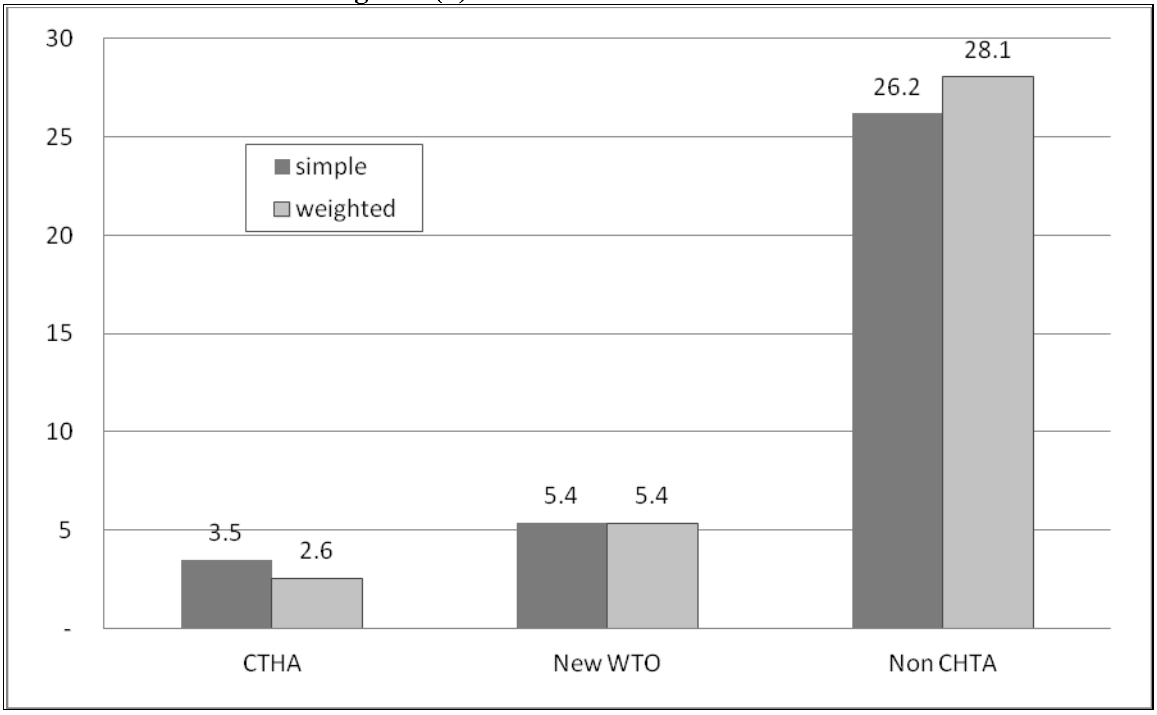


Figure 8(a). MFN Tariffs by HS Chapter (CTHA Participants, simple average)

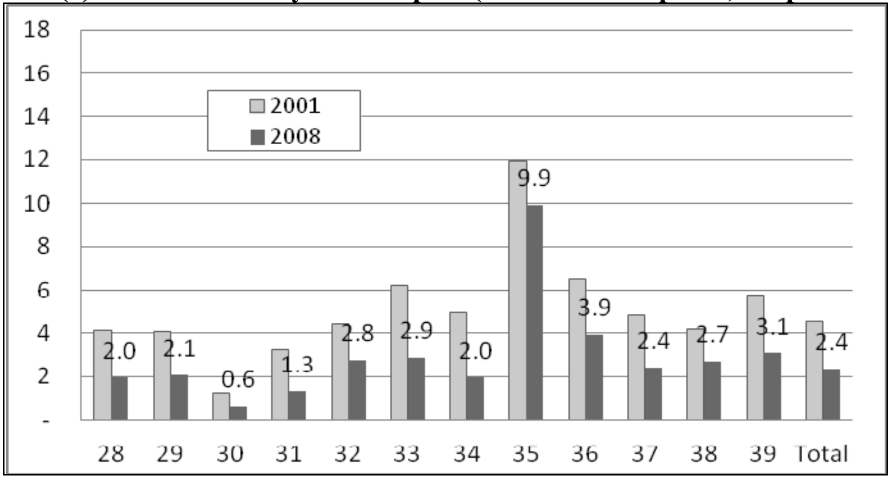


Figure 8(b). MFN Tariffs by HS Chapter (new WTO members, simple average)

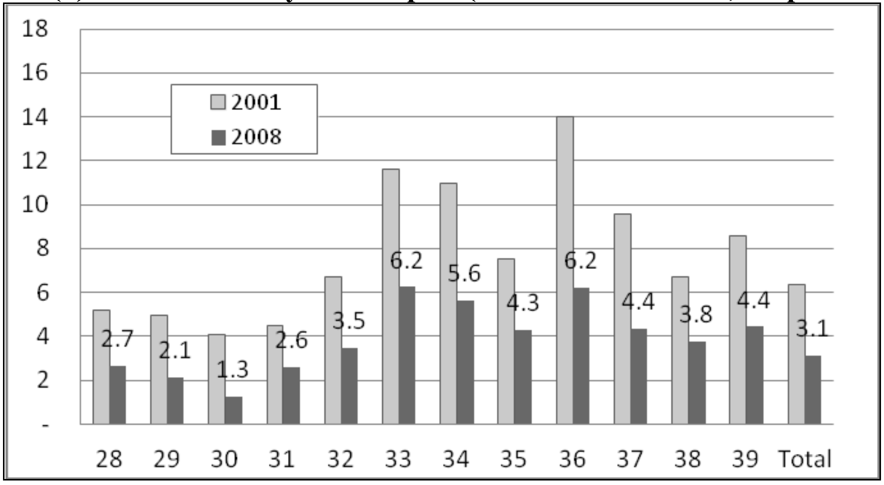


Figure 8(c). MFN Tariffs by HS Chapter (non-CTHA Participants, simple average)

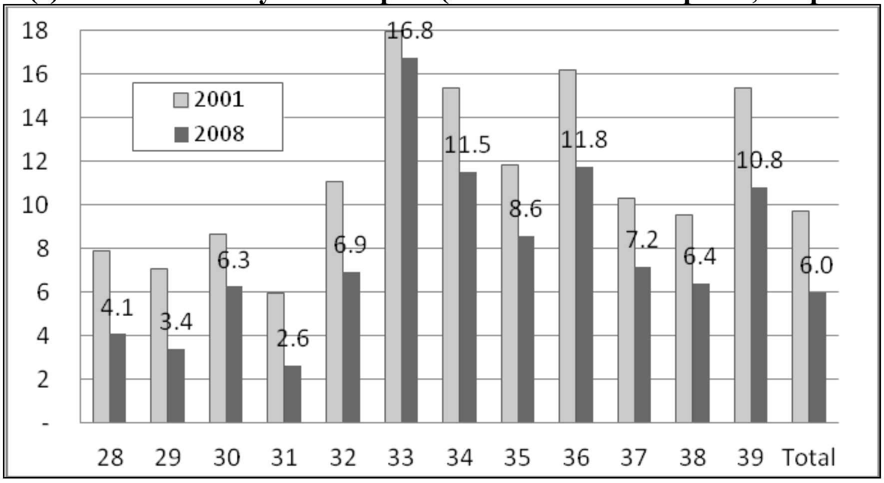
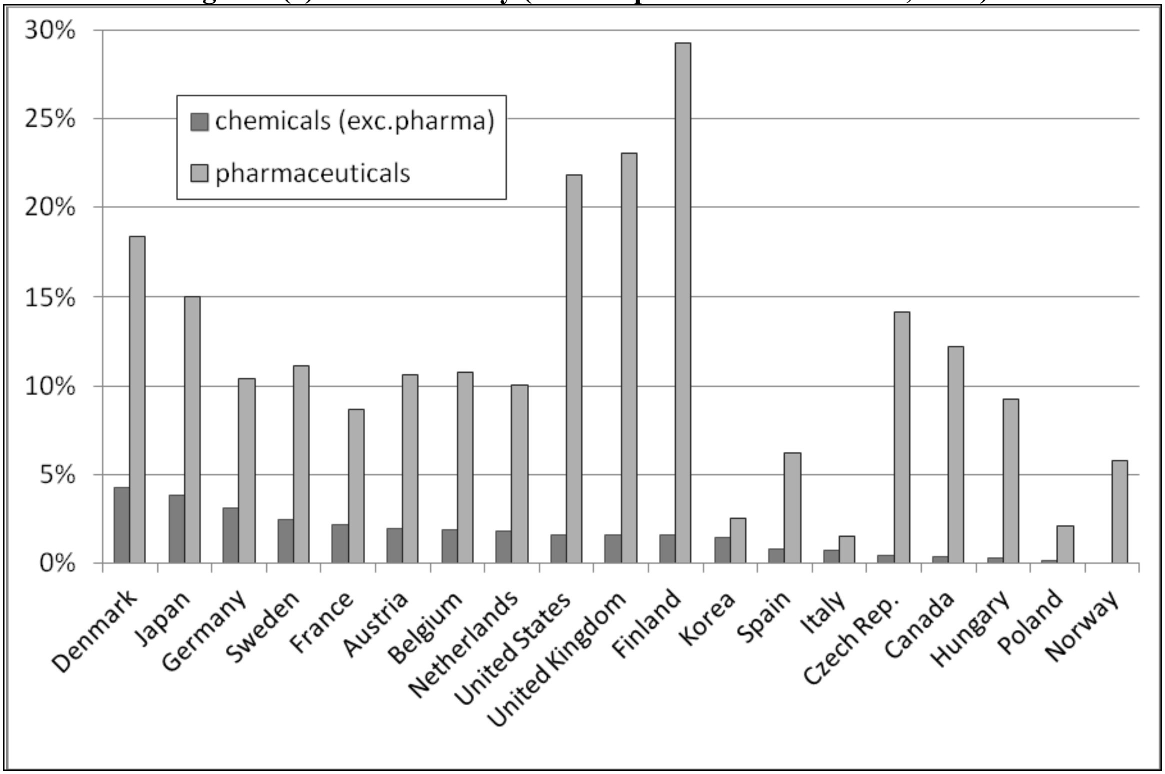
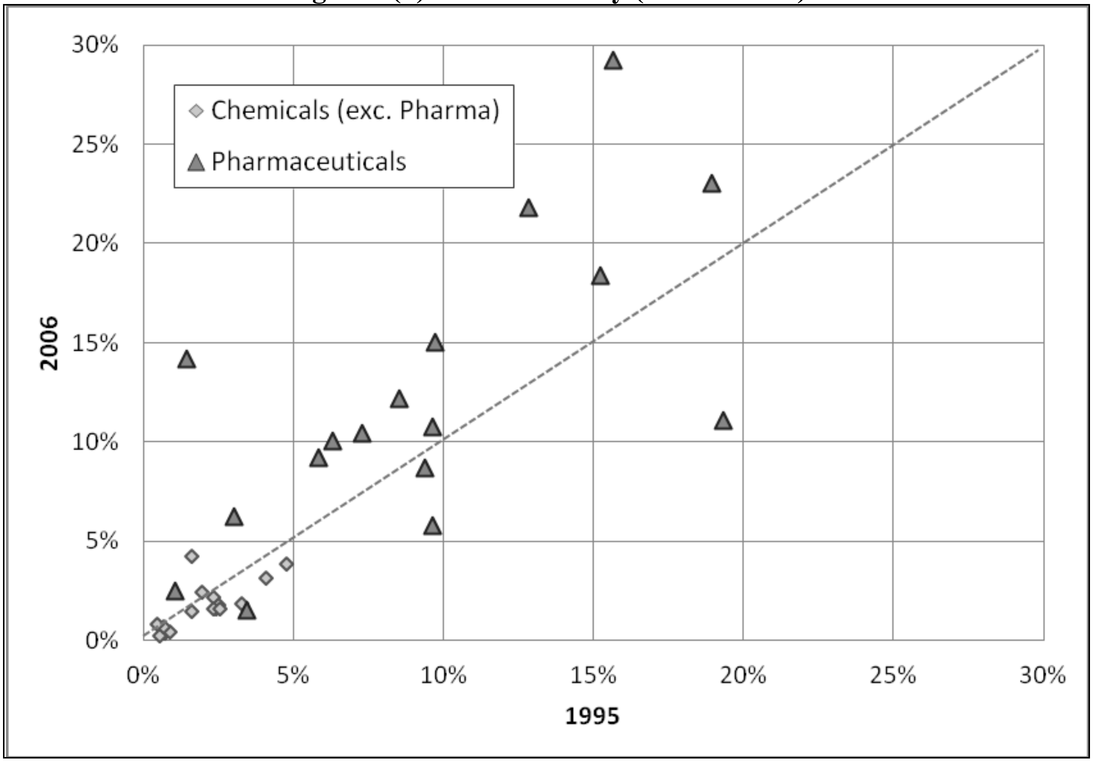


Figure 9(a). R&D Intensity (R&D expenditure/Production; 2006)



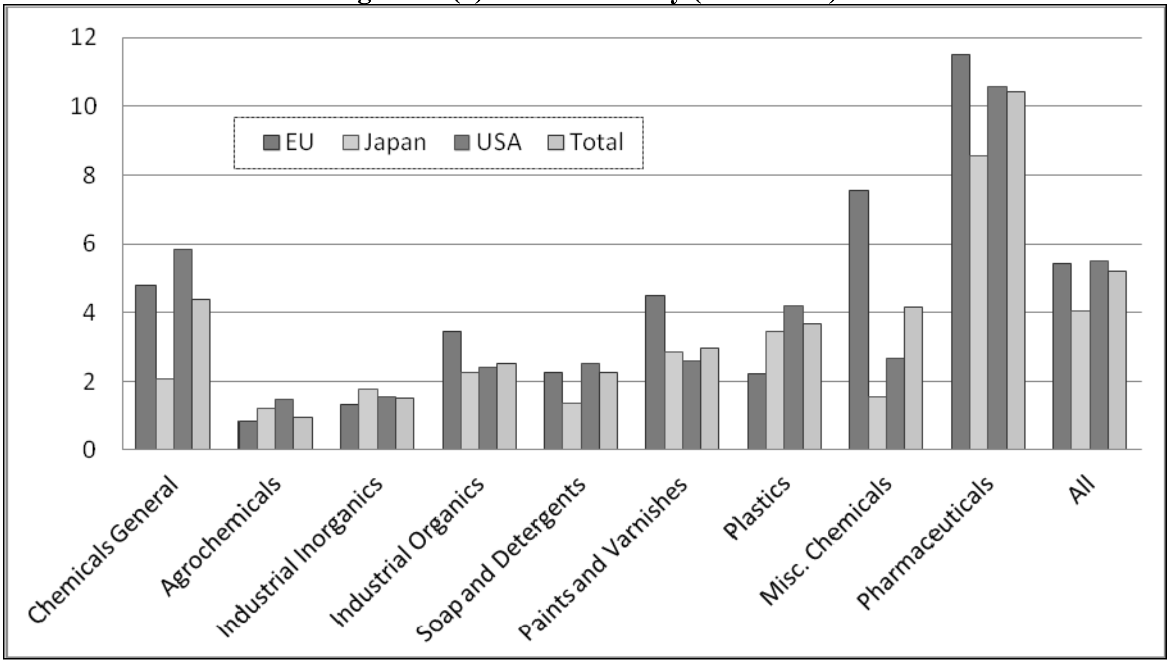
Note: Data for Canada is of 2005; no data available for chemicals (except pharmaceuticals) for Norway.
Industry classification is based on "main activity", except Belgium, Finland, France, Sweden and UK (based on "product field").

Figure 9(b). R&D Intensity (1995 v. 2006)



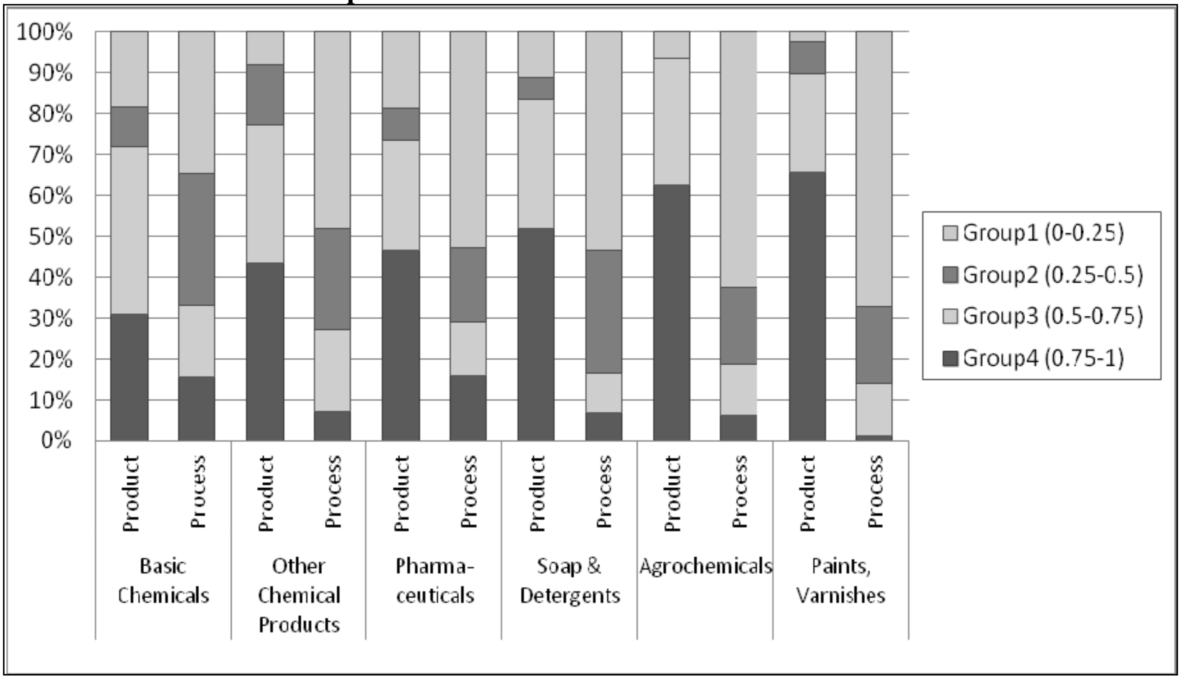
Data included: Belgium, Canada, Czech Rep., Denmark, Finalnd, France Germany, Hungary, Italy, Japan, Korea, Netherlands, Norway (pharmaceuticals), Spain, Sweden, United Kingdom, United States.

Figure 10(a). R&D Intensity (1985-1997)



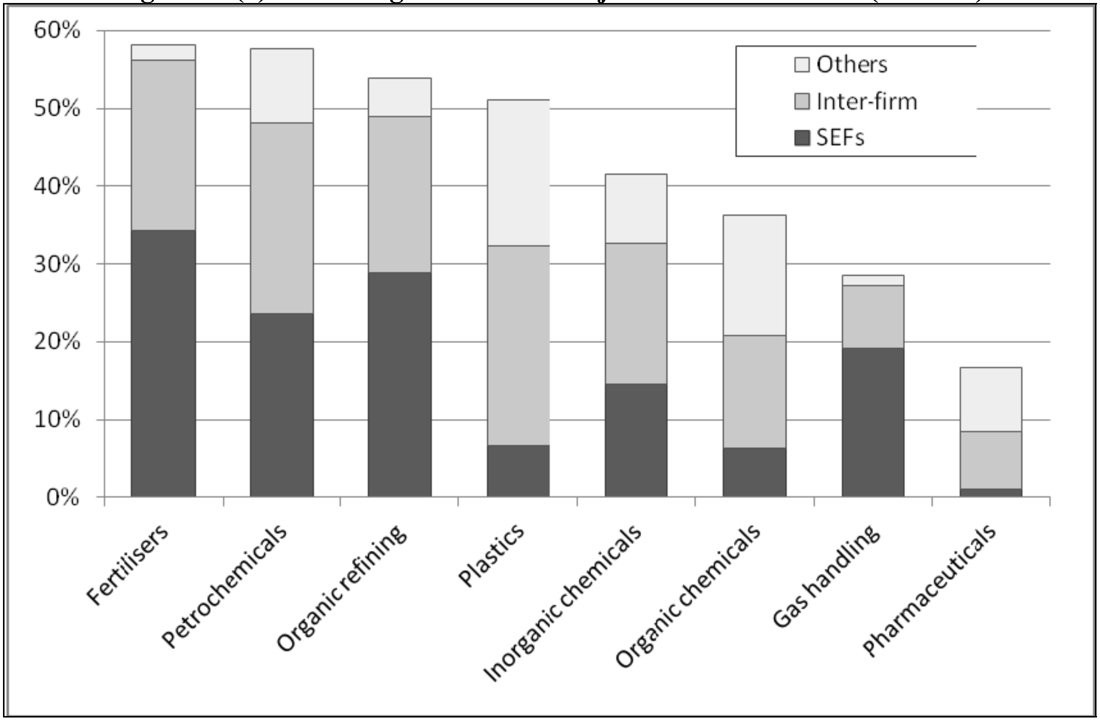
Source : Fleischer et al. (2000), p.85.
Note : Based on 392 firms in three regions. Sectoral classification is made with respect to each firm.

Figure 10(b). Distribution of European Chemical Firms according to their Shares of R&D Expenditure for Product/Process Innovation



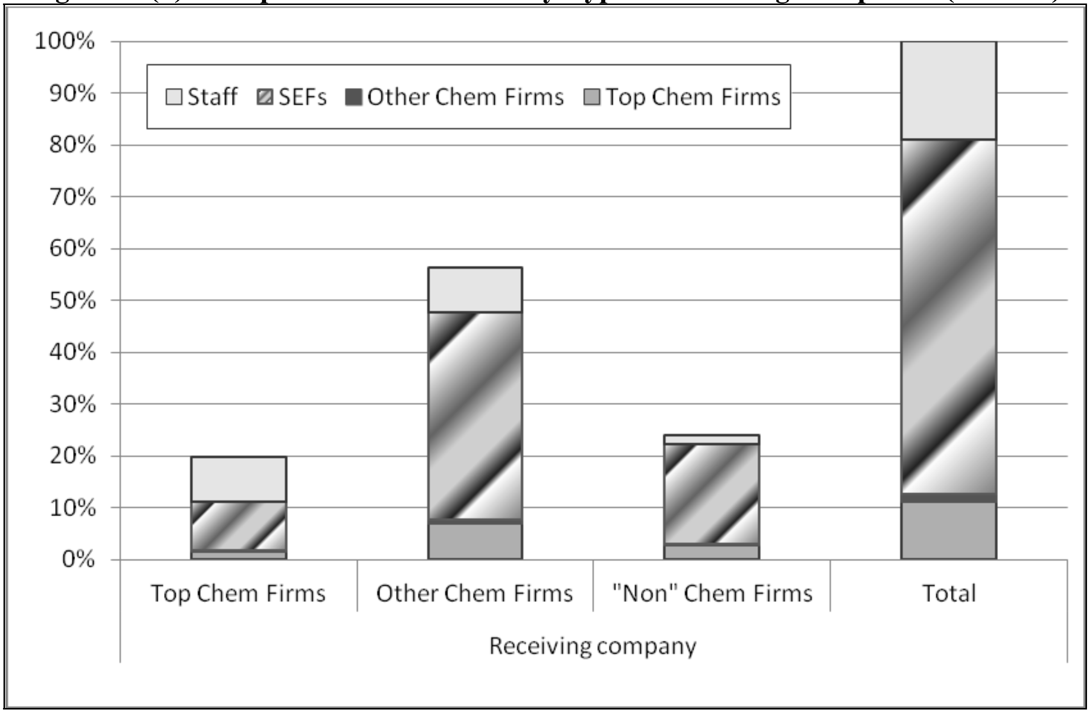
Source : Albach et al. (1996), p.46 ; based on Community Innovation Survey (CIS) 1992/93.

Figure 11(a). Licensing Patterns in Major Chemical Sectors (1980-90)



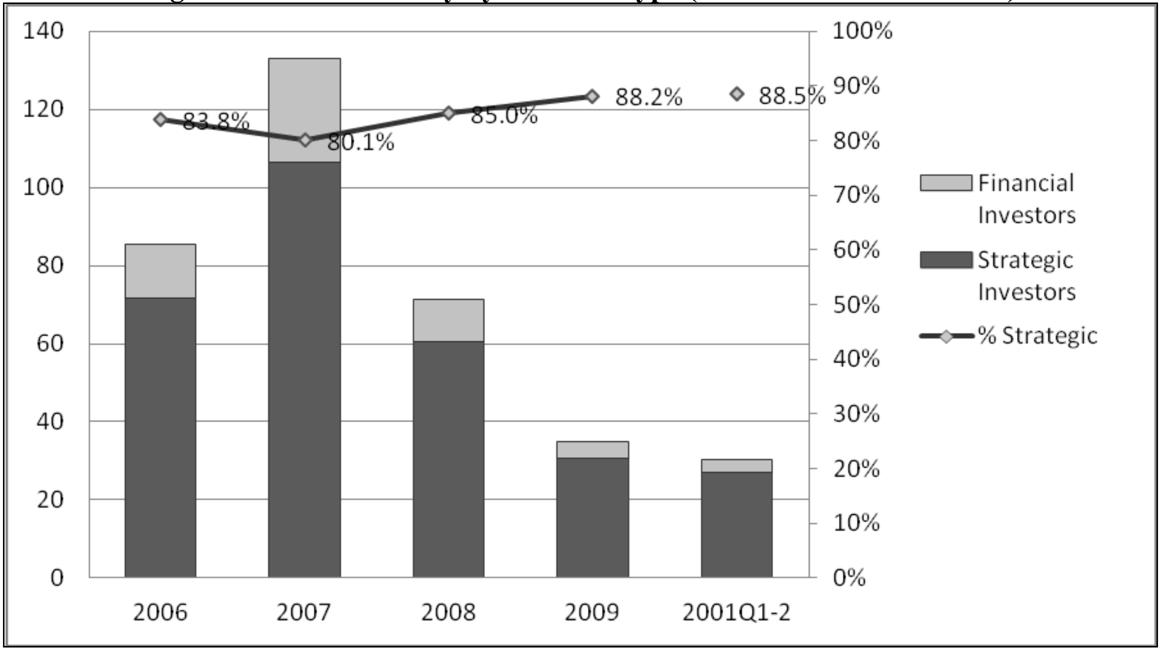
Source: Arora (1997), Table 2 (sub-sectors with larger reported total projects).
Note: The columns represents the percentage share in new plants."SEFs" represents reported licenses sold by SEFs; "Inter-firm" represents reported licneses sold to unaffiliated firms other than SEFs; "Others" includes licenses to subsidiaries and firms that have a common patent.

Figure 11(b). Composition of Licensors by Type of Receiving Companies (1980-90)



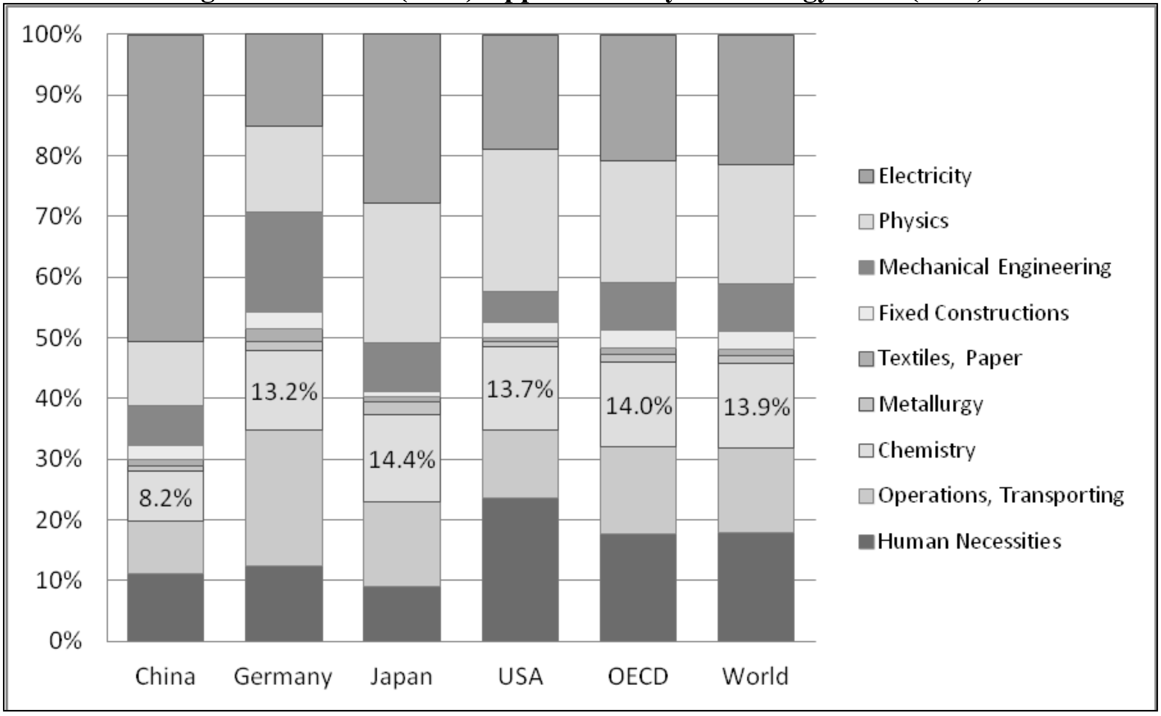
Source: Cesaroni et al. (2004), p.145, Table 4.6

Figure 12. M&A Activity by Investor Type (deal value in billion USD)



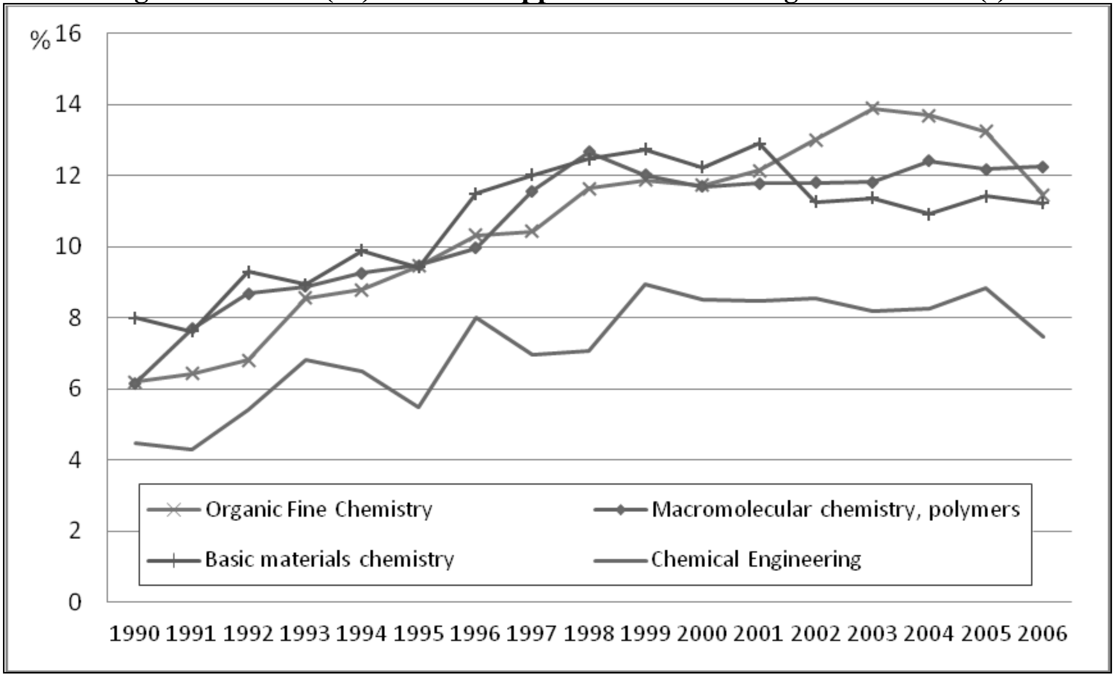
Source: PwC (2010b)

Figure 13. Patent (PTC) Applications by Technology Area (2007)



Source: OECD Patent Database

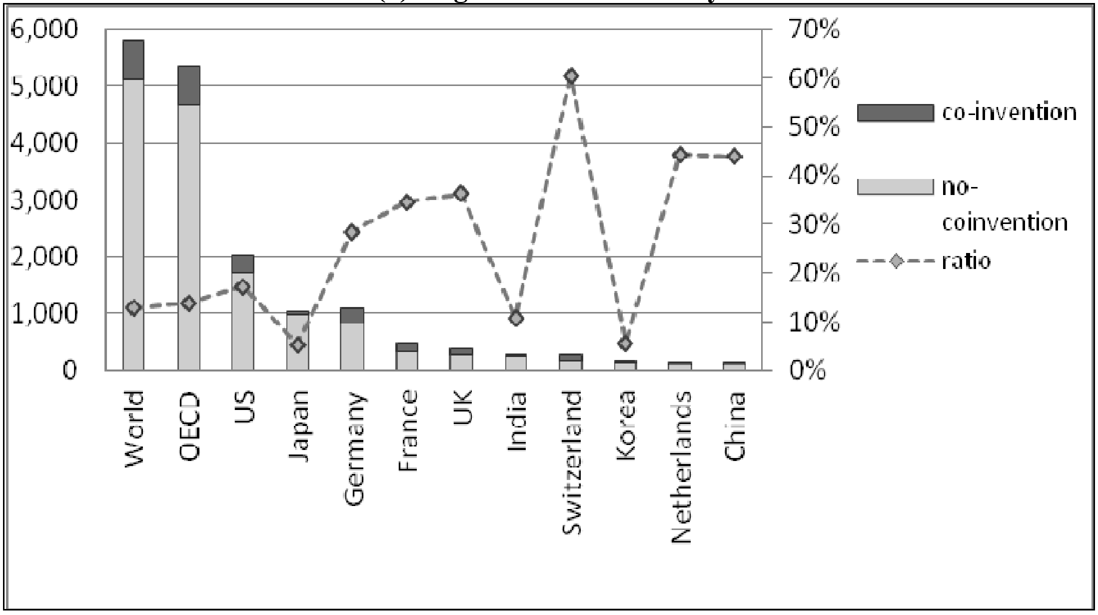
Figure 14. Share (%) in Patent Application with Foreign Co-Inventor(s)



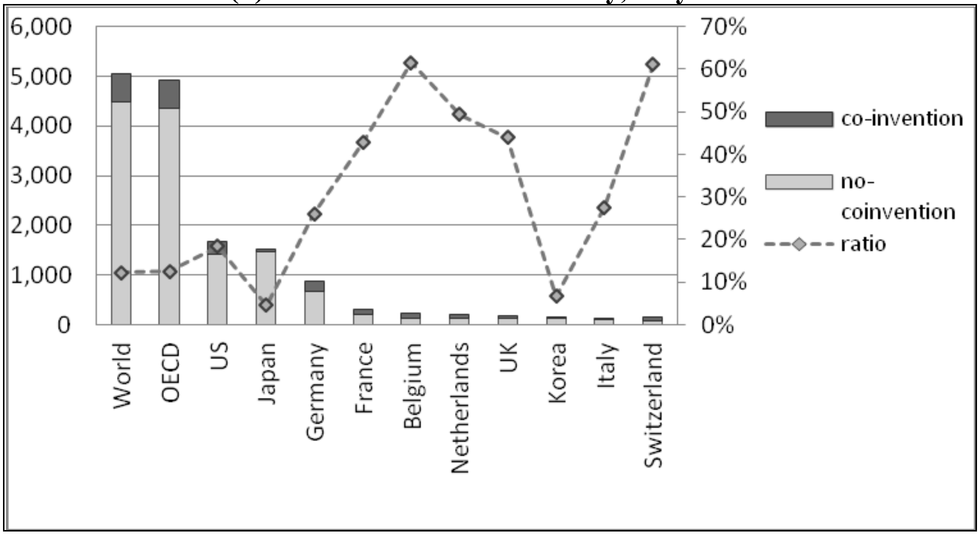
Source: OECD Patent Database

Figure 15. Share in Patent with Co-Inventor(s) (2004-06 Average):

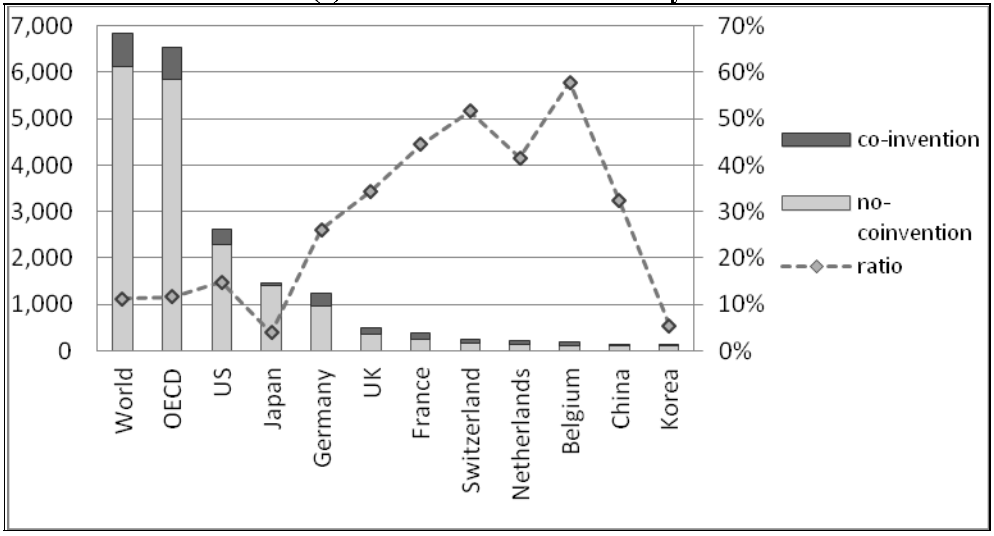
(a) Organic Fine Chemistry



(b) Macromolecular Chemistry, Polymers



(c) Basic Materials Chemistry



(d) Chemical Engineering