The Porter Hypothesis Revisited:

A Literature Review of Theoretical Models and Empirical Tests

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1 LIST OF ABBREVIATIONS

BOD	Biological Oxygen Demand
CFC	Carbofluorocarbons
COD	Chemical Oxygen Demand
EMAS	Eco-Management and Audit Scheme
EPA	U.S. Environmental Protection Agency
EU	European Union
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
IMF	International Monetary Fund
IPPC	Integrated Pollution Prevention and Control
ISO	International Standards Organization
OECD	Organization for Economic Co-Operation and Development
OLS	Ordinary Least Squares
R&D	Research and Development
SO_2	Sulphur Dioxide
SS	Suspended Solids
UK	United Kingdom
U.S., US	United States of America
WTO	World Trade Organization

2 INTRODUCTION TO THE TOPIC AND STRUCTURE OF THE ANALYSIS

The debate on the relationship between environmental regulation and competitiveness has been a topic of debate for a number of years now. As early as 1991, the American economist Michael E. Porter introduced a new perspective to this debate. He proposed and subsequently elaborated, that stringent environmental regulation (under the condition that it is efficient) can lead to win-win situations, in which social welfare as well as the private net benefits of firms operating under such regulation can be increased. This is the so-called Porter hypothesis (Porter 1991; Porter & van der Linde 1995).

Whilst it is not surprising that environmental regulation increases social welfare (which usually is the very reason of introducing it), Porter's predictions about the effect of stringent regulations on private costs and benefits have been an issue of (sometimes heated) argument. One important reason for net benefits of stringent regulation at the firm level, which is often cited by Porter and supporting colleagues is that such regulation can induce innovatory activities in firms which increase their competitiveness.

Opponents of the Porter hypothesis criticize its hidden assumption that firms systematically overlook opportunities for (voluntarily) improving their environmental performance that would also increase their competitiveness. Metaphorically they argue that it is impossible to find a 10-Dollar bill on the ground because if it were there, somebody else would have picked it up already. Another aspect of the Porter hypothesis frequently criticized is the assumption that existing regulatory regimes are able to design stringent and at the same time efficient environmental regulation. Given the historically strong emphasis on command-and-control regulation in many countries (e.g. Germany) this critique indeed seems to have some merit.

This working paper wants to assess the Porter hypothesis with regard to two aspects. Firstly, it will analyse the theoretical reasoning behind the hypothesis by discussing and analyzing the arguments brought forward in favour of and against the hypothesis. This will be based on a discussion of different theoretical analyses and models by various authors in the field. At the end of this section, the working paper will attempt a comprehensive assessment as regards the theoretical validity of the Porter hypothesis. Also it will try to formulate conditions under which a favourable (i.e. mutually reinforcing) relationship between environmental regulation and competitiveness exists.

Secondly, the working paper wants to review influential empirical studies trying to test the Porter hypothesis. This again will be based on the work of various authors and the attempt will be to (after comprehensively presenting each study) compare the different studies with regard to their conditions and results. One important tool in the review of empirical studies is so-called 'meta-analysis' and this working paper will attempt to make use of this tool by also analyzing available meta-studies on the subject. The analysis of empirical work will allow (at least to some degree) assessing whether the theoretical conclusions about the Porter hypothesis are confirmed by empirical research. This will provide further assurance on the conditions under which the hypothesis holds and will thus provide important infor-

mation for future policy making. The working paper will close with a comparison between theory and empirical evidence and with conclusions that will also point to future research needs.

In proceeding like this, the working paper aims to contribute therefore to both, more practical policy making aspects and more theoretical research issues and hopefully provides new insights on both of them.

Prior to any (theoretical or empirical) analysis it is necessary to precisely define the core concepts referred to in the Porter hypothesis, i.e. environmental regulation and competitiveness. This concerns both theoretical as well as empirical aspects and the introduction and discussion of these core concepts will therefore form the Chapters 2 and 3 of the thesis. Chapter 4 will comprise of the theoretical aspects, whilst Chapter 5 discusses empirical work. Finally, Chapter 6 of the working paper will present a comparison and conclusions.

3 TYPES AND PERFORMANCE ASSESSMENT, STRINGENCY AND EFFICIENCY OF ENVIRONMENTAL REGULATIONS

3.1 Environmental regulation: types and performance assessment

3.1.1 Introduction

In the literature on environmental economics, mainly three instruments are distinguished for environmental regulation (see e.g. Endres 1994). These are standards/emission limits, taxes (based on the Price-Standard approach) and certificates (Baumol & Oates 1971; Endres 1994; Zimmermann 1996). In addition to these, liability law can be considered as an additional approach for environmental policy making, since liability law has significant effects on distribution and allocation (Endres 1991). It should be noted that the three types of instruments listed all have the common objective to limit the total emissions in a defined space or on a defined surface. All of them also represent government interventions into the market system in order to correct for market failures, thereby implicitly risking state failure (see e.g. Jänicke et al. 1989; Jänicke et al. 1992; Simonis (1989) on these and related aspects and Endres & Querner (1993) on a discussion in the context of resource economics).[1]

The remainder of this chapter will describe the different instruments for environmental regulation and will then assess them with regard to a number of criteria for environmental policy making.

3.1.2 Types of instruments for environmental regulation

Emission limits and standards

Emission limits/standards are an instrument which defines for all emitters a specific upper limit of emissions. This can be defined either in absolute terms or relative to a specific base unit, e.g. as emissions per unit of volume. An emission limit is defined in such a way, that the sum of all upper emission limits for all emitters is equal to a predefined (regional or national) emission limit. Emission limits/standards can also prescribe a specific technology, thereby reducing the discretion for individual emitters (Endres 1994).

Environmental Taxes and Charges

Taxes are a standards-oriented instrument, which levies the same tax level on each emitter (e.g. a firm). It needs to be set in a way that the added emissions of emitters do not exceed the emission levels predefined by regional or national emission ceilings. Whilst however a Pigouvian tax results in a Pareto-optimal emission level, the taxes discussed here are based on the Price-Standard approach (Baumol & Oates 1971), which achieves

[1] Opposed to this the common internalisation strategies (either based on the 'polluter pays' principle and Pigouvian taxes or by means of negotiation solutions based on Coases's theorem and the Property Rights approach) have the primary objective to allocate the monetarised damage caused by economic activities, i.e. to internalise external effects and corresponding costs, in order to return to a Pareto-optimal situation (Endres 1994).

a specific emissions level/target that does not however have to be necessarily Pareto-optimal (Endres 1994).

Tradable and Transferable Emission Permits and Certificates

Tradable emission certificates or transferable emission permits are a standards-oriented instrument, which gives an emitter a right to emit a defined amount of a specific pollutant in a defined region or area. Therefore, each emitter needs to cover its total emissions with ownership of a sufficient number of emission certificates/permits. Each permit in this allows the owner to emit a defined amount of a specific pollutant under precise temporal and spatial conditions (e.g. emission only from a point or non-point source). The sum of the allowed emissions which correspond to the total of permits/certificates put in circulation (or more precisely, of their nominal value) equals the predefined (regional or national) emission level/target (Endres 1994).

3.1.3 Criteria for assessment of different types of instruments

A number of criteria can be used to assess different regulatory instruments from an economic point of view. The four most important ones to be used in the following are (cost) efficiency, dynamic incentive effects, aspects of competition and structural policy and the environmental effectiveness of an instrument.

Efficiency

One basic distinction in the assessment of different instruments for environmental regulation is the one between market-oriented and judicially-oriented (command-and-control) types of instruments. An instrument is market-oriented, if it makes use of the market mechanism in order to achieve a predefined emissions level. Under the ideal conditions of perfect competition, this would lead to a Pareto-optimal realisation of the predefined emission level. This characteristic of an instrument for environmental regulation can be described as its efficiency (Endres 1994).

Dynamic incentive effects

Next to efficiency, another important criterion is the degree to which an instrument induces technological change. Technological change can be observed in terms of changes in the efficiency of the use of factor inputs in production (Martiensen & Wenig 1993, p. 66). An instrument would be judged the more positive on this assessment criterion, the more technological progress it induces. This refers to both, the rate as well as the direction of technological change. For a market-oriented instrument, it seems to be indispensable to induce at least a minimum amount of technological progress (ultimately seen as an improvement of the state of technology) over time, which is very unlikely in the case of emission limits/standards (see Endres (1994) for a detailed discussion of this aspect and its link to the state of technology/prescription of specific technologies). This second assessment criterion will be referred to in the following as an instrument's dynamical incentive effects (Endres 1994).

Aspects of competition policy and structural policy

These aspects refer to the degree to which regulatory instruments distort competition or have a negative effect on structural or regional policy objectives. For example with a strict predefined emission level, the expansion of existing and the entry of new firms into the market is not possible anymore. In addition to this, when distributing emission rights under a strict predefined emission level according to the seniority principle, older but possibly inefficient companies are protected further, thus reducing the intensity of competition in the region and ultimately leading to negative effects on competition and structural policy (Endres 1994). Opposed to this, with both, taxes and certificates, the phasing-out of inefficient plants is fostered. However, other than for taxes, with certificates the predefined emissions level is achieved even if structural change (in terms of phasing-out of inefficient plants taking place). Therefore, no state intervention is necessary and the problem of a tax-based policy that remaining at or below the predefined emission target whilst at the same time enabling economic growth is avoided (Endres 1994).

Environmental effectiveness

Environmental effectiveness as the fourth criterion commonly used for assessing different types of regulatory instruments can be defined as its ability to achieve a predefined environmental target (Endres 1994). Environmental effectiveness itself has a number of subaspects referring to the precise definition of an exogenous target, the required adaption time to achieve the target under the instrument chosen, issues of objective-means interdependency in the process of realizing the target and the issue of emission reductions without a defined target (Endres 1994).

3.1.4 Summary of assessment of different regulatory instruments

In summary, the different (positive and negative) effects of the different regulatory instruments (in their ideal forms) can be evaluated with regard to the different assessment criteria laid out in the previous section. This has been done in the following Table 1.

Table 1: Assessment of regulatory instruments for environmental policy

Criterion	**Standards**	**Taxes**	**Certificates**
Efficiency	-	+	+
Dynamic incentive effects	-	+	+
Structural and regional policy effects and distortions of competition	-	+	+
Environmental effectiveness	+	-	+

What can be seen from Table 1 is that taxes and certificates can be differenttiated very clearly from a standard in terms of its economic profile (efficiency, dynamic effects etc.). This explains why the former instruments are frequently labeled to be 'market-based' and the latter to be 'command-and-control' (Endres 1994; Pearce 1993).

As concerns environmental effectiveness, this is highest for standards and permits/certificates, yet uncertain for taxes. However it has to be taken into account here the dynamic incentive effect of the instruments as well. This is because the development of new, more efficient, technologies for emissions reduction depends on the instrument chosen. This means that even whilst leading to higher emissions in the (static) short term, an instrument with higher incentive effects with regard to technology development may in the longer term lead to higher emission reductions since it has more potential to achieve a move towards a more efficient production function (Geschwendtner 2000). As will be seen in the next section, this aspect is pivotal to the Porter hypothesis.

3.2 Stringency and Efficiency of Environmental Regulations

As can be seen from the differing assessment of instrument types for environmental regulation, one of the important factors for the relationship between environmental regulation and economic competitiveness are regulatory stringency and efficiency. This concerns e.g. performance versus ambient standards, mandated end-of-pipe technology versus clean technology/clean production, process change versus demand side measures, legislation versus economic instruments (such as price- or incentive-based regulation), cooperative versus confrontational industry-regulator relationships (e.g. forced vs. voluntary/negotiated agreements).

With regard to level, efficiency and future developments in regulation, it can be expected that the relationship between environmental regulation and economic competitiveness will be stronger positive in countries and sectors with a more efficient approach to regulation. For example, Jaffe et al. (1995, p. 135) point out that keeping ".. constant the *stringency* of environmental standards, the *form* these rules take can potentially affect business location [italicised as in the original, M.W.]" or, it could be argued, competitiveness in general.

Next to the strictness/stringency of environmental regulation, it is also necessary to consider the efficiency of regulation depending on the instruments used. From the point of economic theory it is usually argued that the use of economic instruments is more efficient than a command-and-control approach. However, it has also to be taken into account, to what degree regulations are designed and implemented efficiently (as it may be that command-and-control legislation can be implemented more efficiently than economic instruments).

Efficiency of regulation is an important issue in empirical testing the Porter hypothesis i.e. the idea of a 'double dividend' between tough environmental regulations and economic competitiveness, based on the notion that stringent environmental legislation at the national level will in the longer run lead to competitive advantages of the regulated firms (Porter 1991). This is because properly designed environmental regulation can produce

organisational and technical innovations which lead to production efficiency gains that may result in absolute advantage over non-regulated firms (Porter & van der Linde 1995)[2]. However, as Romstad (1998) points out, in order to empirically test the Porter hypothesis, it has to be assumed that regulations are efficient, since if this condition is not met, any empirical rejection of the hypothesis could be based on increased costs from the inefficiency of regulation, instead of a direct negative effect of regulations on firm's competitiveness.[3]

From the assessment of different types of instruments for environmental regulation in Chapter 2.1 it becomes clear that taxes and certificates are likely much more suited to bring about effects such as those proposed in the Porter hypothesis than are emission limits/standards. The expectation is that this will also be reflected by the theoretical and empirical work on the Porter hypothesis that will be discussed in Chapters 4 und 5.

[2] One core question is consequently how environmental pressures influence the rate and direction of technological and organisational change within firms.

[3] In so far evidence in Scandinavia (Brännlund et al. 1995) and in the United States of America (Jaffe et al. 1995) against the Porter hypothesis has to be treated cautiously, since regulation in both countries is inefficient (Hahn 1989; Brännlund et al. 1995).

4 THE CONCEPT OF COMPETITIVENESS: ITS THEORETICAL DEFINITION AND EMPIRICAL MEASUREMENT

4.1 Introduction: the concept of international competitiveness

The concept of competitiveness of nations has been very influential for the economic and political debate of the 1990s. Competitiveness for example was a major driving force behind the Single Market in the European Union (EU) in order to capture economies of scale and to break down competitive barriers (CEC 1993). It had also considerable influence on corporate environmental management. Thompson (1998) identifies five independent trends that brought competitiveness at the forefront of the debate:

1. The collapse of the Cold War and thus the struggle between two ideological formations which locked all world issues into a single geomilitary dimension,

2. The (perceived) unsuccessfulness of large-scale and national initiatives on 'industrial policy' and 'industrial strategy',

3. The trend towards policies of liberalisation, de-regulation and privatisation, which, although often perceived as a result of internationalisation and globalisation of economic activity, are suggested to be driven rather by domestic decisions and policy changes (Thompson 1998),

4. The 'success' of inter-governmental organisations such as the Organization for Economic Co-Operation and Development (OECD), the World Trade Organization (WTO), the International Monetary Fund (IMF) and the World Bank in opening-up the world economies and in reducing protectionist barriers,

5. The increased interdependence and integration in the world economy since 1945.

According to Thompson (1998), these five trends raised the importance of the relative competitiveness of different countries and resulted in mainly three explanatory frameworks for differences in competitiveness, which are:

(i) The Domestic Interests approach, which stresses similar patterns and processes for understanding the relative economic performance of national economies,

(ii) The Actor-Interactions approach, which stresses the interactions between key actors in the conduct of international relations (rather than domestic interests), and

(iii) The Geoeconomic approach, which has a less explanatory stance and stresses the strategic interrelationship between the three main groups in the international economic system, as well as the importance of redefining the nature of international security after the collapse of the Cold War and the decline of United States of America (U.S.) hegemony (Thompson 1998).

4.2 Definitions and measures of international competitiveness

In the discussion on the relationship between environmental regulation and competitiveness, several definitions of competitiveness are referred to. The OECD, for example, de-

fines international competitiveness as "the degree to which (a country) can, under free and fair market conditions, produce goods and services which meet the test of international markets, while simultaneously maintaining and expanding the real incomes of its people over the longer term (OECD 1992, p. 237)".[4] Alternatively, Boltho (1996) defines short-term international competitiveness as "… equated with the real value of the exchange rate (p. 3)" and long-term competitiveness as "… virtually synonymous with trend productivity growth (p. 3)".

Other measures that are mainly used to assess international competitiveness of nations are changes in unit labour costs, changes in the share of world exports of goods and services, and foreign direct investment (FDI) performance of countries. In summary, a number of measures of international competitiveness of nations have been identified (Barker & Köhler 1998; Jaffe et al. 1995, pp. 137-138; Thompson 1998).

The above OECD definition refers to the "capacity to sustain and increase a country's participation in international markets, by being able to meet standards of efficiency (regarding the use of factors of production and natural resources) and product quality of the rest of the world (OECD 1992, p. 237)". In doing so, it points to the fact that 'competitiveness' achieved by means of exchange rate devaluations, low domestic wages and public expenditure cuts is generally associated with reduced real income. Thus only the ability of a country to secure sales in the international market should result in increased domestic welfare (Hopkins & Cabalu 1993). However, this definition is rather qualitative and thus difficult to measure based on national economic accounts. For this purpose, the quantitative measures of real exchange rate value and trend productivity growth as measures for short- and long-term competitiveness respectively are more appropriate. Nevertheless, their adoption can also lead to problems (Hopkins & Cabalu 1993, pp. 15-27). In the case of the real exchange rate for example, these relate to the use of different indices, weighting systems, and its relationship to a country's trade balance (Hopkins & Cabalu 1993, pp. 15-18).

4.3 The use of empirical competitiveness measures for measuring the competitiveness of industries and firms

A key question is to what extent measures of international competitiveness at the national level are relevant for an analysis at the industry/sectoral or firm/site levels. Overall, since only a small percentage of a country's product (i.e. its Gross Domestic Product, GDP) is usually exported, the emphasis on trade and international competitiveness measures may be overstated and changes in national productivity (independent of international competitive/foreign trade considerations) may be considerably more important since a large part of the economic success is based on a 'sheltered' domestic sector (Thompson 1998). This is even more so in countries with a low degree of export orientation.

[4] This definition was originally proposed by the U.S. President's Commission on Industrial Competitiveness in 1995.

Consequently, productivity improvements (esp. labour productivity) and conditions internal to firms may be more important sources of competitiveness, with cheap and abundant labour, natural resources and favourable exchange rates being less relevant, in particular when considering effects of environmental regulation (Jaffe et al. 1995, p. 138). In this view, national prosperity is not inherited, but created by the capacity of a country's industry to innovate and to employ new technologies (Porter 1998). This leads to increased product quality, improved product technology and increased production efficiency. The key factors that determine success in achieving this (and in doing so support high wages and command high prices in international markets) are (Porter 1980; 1998):

- availability of factors of production, including skilled labour and infrastructure;
- nature and level of domestic demand;
- availability of internationally competitive supplier industries; and
- conditions governing the creation, organisation, and management of firms and those governing domestic competition.

This is the so-called 'diamond of national advantage' (Porter 1985; 1998) in which all factors interact and reinforce each other.

Although measures such as trend productivity growth address this caveat of measures for international competitiveness based on trade theory and comparative cost advantages, it is advisable to use measures that more directly (i.e. at the industry and firm levels) assess the effect of environmental regulation on firm's productivity and consequently their economic performance, such as e.g. true costs of environmental protection.

Another argument why not to use national competitiveness measures (e.g. changes in net exports or the pattern of imports and exports, or FDI performance), but more direct measures to assess the effect of environmental regulation on firm's economic performance may be that the evidence gathered using competitiveness measures at the national level for the U.S. does not provide much support against the Porter hypothesis (Jaffe et al. 1995)[5]. This may mean that other macro-level trends and influences are too strong to single out the effect of stringent environmental regulation on these measures, requiring the use of more detailed measures at the meso- or micro-levels to detangle their effects from general economic effects (such as inflation processes, exchange rate changes, or economic recession for example).

It could also mean that the above evidence supports the arguments brought forward for example in the Ecological Modernisation debate (Simonis 1989; Jänicke et al. 1989;

[5] This is not too unexpected, given the small share (of around 2 percent in industrialised countries) that direct costs of environmental protection have at the macroeconomic level in national GDP (Jaffe et al. 1995; Luken 1997; Silveira 2000). Since the U.S. have almost the highest share of direct compliance costs in GDP it can be argued that results for them are to some extent an upper limit estimate of the impact of environmental regulation on competitiveness. Jaffe et al. (1995) note however that whilst international differences in environmental costs are relatively small, (compared to labour cost and productivity differentials) inter-industry variation of environmental costs in the U.S. is very high. (p. 142).

Jänicke et al. 1992) i.e. the view that economic growth (based on increased or maintained national competitiveness) can be decoupled from environmental pollution.

Next to the conceptual limitations of competitiveness measures at the national level in measuring international competitiveness satisfactorily, they also seem to be too broad (and as well theoretically problematic) to be used to assess competitiveness at the sector or firm levels, since countries do not engage in competition in the same way that firms do (Krugman 1994). This is, because the concept of international competitiveness discussed so far refers only to national economies and is fundamentally rooted in conventional trade theory where economies always have some form of comparative cost advantage. A comparative advantage of one country over another in a broad factor of production is however only one source of the national competitiveness of a country.

Beyond such comparative advantages, many other levels of competitiveness exist (Porter 1980; 1985), and as Porter (1998) points out international competitive advantage can often be concentrated in narrowly defined industries or even particular industry segments (such as e.g. the environmental technology industry). Such success of individual companies in specific industries or industry segments can therefore be another source of a nation's competitiveness, other than comparative cost advantages in a broad factor of production (such as labour or capital). Success in this respect is based on competitive advantages, other than comparative advantages, of a firm or a set of firms over their competitors in other countries.

In the case that a country manages to locate a critical mass of (in the sense of competitive advantage) internationally competitive companies on its territory, it will demonstrate national competitiveness, revealed by e.g. increasing shares of world trade or sustained currency appreciation (Thompson 1998). In this, the international competitiveness of a country is essentially the result of competitive advantages in (a possibly relatively small number of) specific industrial sectors or (even narrower) sub-sectoral industrial segments, superimposed with the broad comparative cost advantages the country has.

A reconsideration of the measures of international competitiveness introduced in Chapter 3.2 (real value of the exchange rate, trend productivity growth, changes in unit labour costs, changes in the shares of world exports of goods and services and FDI performance) points to one of the fundamental limitations of the whole debate which is that it concentrates on relatively direct outcome measures of international competitiveness.

This is also mirrored by the claims of the necessity to improve the overall supply side of ailing economies mainly through promotion of specific education and training programmes, increased research and development (R&D) expenditures and creation of an entrepreneurial climate, which are more indirect, leading variables. So far however, only little systematic or robust empirical evidence exists that causally links levels of education or training competencies, R&D expenditures or economic innovativeness, with the discussed measures for international competitiveness of a country (Thompson 1998). However, more correlation was found between the change in R&D expenditure per unit of GDP and the change in market share of exports, than for the correlation between decline

in price competitiveness (measured by unit labour costs) and such change in export shares (Fagerberg 1996). The above theoretical frameworks and measures discussed often neglect the influence technology has on trade and prices by identifying international competitiveness with relative unit costs or prices (Barker & Köhler 1998).

Taken together these results point to the need to also consider non-economic measures to assess the competitiveness of a country and companies. Competitiveness of countries and competition between countries is, as derived above, taking place in a larger frame of reference, which includes characteristics as diverse as living standards or military power. These are however likely to be more influenced by more indirect measures and characteristics, such as the general institutional framework of the labour market, the forms of settlement between social partners and organized interest groups, the form of the financial system, or the constitutional nature of corporate governance systems, rather than the specific economic measures and instruments suggested to improve supply side conditions. Measures that assess the strength of a country with regard to these more indirect measures and characteristics are likely to be more related to rather qualitative aspects of its culture such as the degree of innovativeness, pluralism, political openness and space for a critical 'culture of ideas', than to economic measures of international competitiveness (Thompson 1998)[6]. In conclusion this means that an operationalisation of the concept of international competitiveness should ideally take into account as well more qualitative performance measures to assess a country's potential for international economic performance and success.

4.4 Linking international competitiveness and competitive advantage

As stated earlier, international competitiveness can be understood as being determined by comparative as well as competitive advantages. Although economies always have certain comparative advantages, it is not certain that they will as well always have competitive advantages in certain lines of production (Thompson 1998). One reason for this is, that comparative advantages apply mainly to sectors where success depends on natural comparative factor endowments (such as labour or natural resources), whereas competitive advantages mainly apply to sectors where success can be created and fostered deliberately through changes in organisational structures or behaviour (e.g. manufacturing or services industries). In short, comparative advantage mainly refers to natural conditions of a country (its 'hardware', e.g. resource availability and consequently factor prices) whereas competitive advantage mainly refers to its social conditions (the 'software', e.g. labour conditions, technology availability and R&D activities). The social conditions are influenced for example by bandwagon effects and processes such as positive feedback or learning by doing which potentially lead to cumulative growth trajectories as described in the dynamic modelling literature (Kaldor 1981; Thompson 1998). One consequence out of this is that the attempt to enhance existing domestic competitive structures of sectors

[6] However, although this claim has been often stated, the empirical evidence for it is sometimes weak in that e.g. Pascale and Athos (1982) found that rather than qualitative cultural aspects, a new use and combination of standard managerial ploys is (at least sometimes) a key source of international competitiveness.

where other countries already have a comparative advantage seems not to be very promising, although a co-ordinated attempt to emulate or outperform already in other countries highly successful sectors may well be successful (Thompson 1998).

Another aspect of the relationship between international competitiveness and competitive advantage is the question if countries are competing economically at all. Clearly, countries do not go bankrupt in the same way firms do if they are economically unsuccessful, and, contrary to firms, with nations the bulk of their product (its GDP) is consumed by a nation's own citizens with only a small percentage being exported. Another fundamental difference between firms competing against other firms for shares in a particular market and countries competing against other countries in several markets is the fact that a country's currency exchange rates can vary in a way that offsets long-term competitive advantages of one country over the other (Barker & Köhler 1998). This leads to the conclusion that one cannot easily compare companies and countries with regard to international competitiveness. Based on this, some conclusions that can be drawn from the competitiveness debate and which should be taken into account when analysing empirical studies on the relationship between environmental regulation and competitiveness are discussed in the following final section.

4.5 Conclusions

As was explained earlier in Chapter 3, the notion of international competitiveness of a country is partly misleading, since there are distinct differences between countries and companies (Krugman 1994). Nevertheless, the ability of companies to sell products in competition with companies form other countries is an issue, since it is the competitive advantage of companies that leads to a competitive advantage of a national economy, measured as an increase in its share of world trade or a sustained appreciation of its currency or through similar measures of international competitiveness (Barker & Köhler 1998; Thompson 1998). It is in this sense correct to perceive a country's international competitiveness as (at least partly) determined by the competitive advantage of individual companies, since international competitiveness can be described as the superposition of competitive advantage and comparative advantage. In other words: only if a country has a critical mass of firms with a competitive advantage in a specific sector (over firms in the same industrial sector in other countries) than it will have a visible competitive advantage in this industrial sector. In the next step, the international competitiveness of a country can be disaggregated into the level of sectoral competitiveness in each industrial sector (which is, in turn, determined by the sum of competitive advantages of individual firms). Sectoral competitiveness also varies with the comparative advantage a country has as a result of its natural comparative factor endowments, i.e. competitiveness at the level of industry sectors partly results from the interaction of competitive and comparative advantages, which have rather distinct sources (i.e. comparative advantage is based more on natural conditions, whereas competitive advantage is based more on social conditions of the country in question). The results of the aggregation from firm level to sector level are finally national profiles of sectoral competitiveness, which can be further aggregated to lev-

els of national competitiveness (e.g. based on the change of shares of world exports of goods and services or the changes in unit labour costs).

For the analysis of the Porter hypothesis, an important conclusion is that competitiveness cannot be defined in one unique way, and depending on the definition chosen, findings may differ. Jaffe et al. (1995) suggest as the ideal measure for analyzing the Porter hypothesis and the link between regulation and competitiveness in general the effect that an environmental regulation or policy has on net exports "… holding real wages and exchange rates constant (Jaffe et al. 1995, p. 136)". However, this ideal measure would require to formulate and estimate (with reliable data) "… a structural econometric model in which net exports by industry, wages, and exchanges rates are determined jointly as a function of regulatory costs and resource endowments (Jaffe et al. 1995, p. 137)". Also, this measure would be measuring outcomes, but not drivers for competitive advantage at the level of individual industries.

Prior to reviewing and analyzing, in the Chapters 4 and 5, theoretical reasoning about and empirical studies on the Porter hypothesis it should be noted that the hypothesis has a complement in business management studies and research where the relationship between the environmental and economic performance of firms (and more recently also the link between sustainability performance and competitiveness) is analysed in a similar fashion as has been the Porter hypothesis in economics. Indicative of this body of work, Schaltegger and Synnestvedt (2002) propose a theoretical model for linking environmental and economic performance similar to the ideas behind Porter's hypothesis and Wagner et al. (2002) review a larger body of empirical literature on the relationship between environmental and economic performance at the firm level concluding that at least firms are not penalized for improving environmental performance in terms of deteriorating economic performance.

5 THEORETICAL ANALYSIS OF THE PORTER HYPOTHESIS

5.1 Introduction

The theoretical debate surrounding the Porter hypothesis started almost immediately after the initial papers by Porter (1991) and Porter and van der Linde (1995) were published (e.g. Palmer et al. 1995). Nevertheless, detailed formal models emerged only somewhat later in the debate (e.g. Simpson & Bradford 1996; Romstad 1998; Xepapadeas & de Zeeuw 1999; Lankoski 2000; Alpay 2001; Mohr 2002). This chapter wants to initially discuss (in Chapter 4.2) arguments for the validity of the Porter hypothesis, based on Porter's and his colleagues own arguments, as well as briefly review the critique by others of these initial arguments. Following this (in Chapter 4.3), a number of relevant formal models shall be briefly reviewed with regard to their structure and outcomes. This will assist in identifying factors and conditions under which the Porter hypothesis is most likely to hold and which limit the area of validity of the Porter hypothesis. The chapter concludes (in Chapter 4.4) with a summary of key results and conclusions from theoretical analysis of and reasoning about the Porter hypothesis.

5.2 The basic arguments concerning the Porter hypothesis

The basic argument of the Porter hypothesis was initially formulated in a one-page article (Porter 1991) and was subsequently elaborated on by Porter and van der Linde (1995) as well as Esty and Porter (1998). Porter (1991) states that "strict environmental regulations do not inevitably hinder competitive advantage against foreign rivals (p. 96)". This is the basic idea behind the Porter hypothesis. The starting point of the analysis is "… that the environment-competitiveness debate has been framed incorrectly (Porter & van der Linde 1995, p. 97)". Porter and his co-workers point to the central role of innovations and identify as the main theoretical argument for the Porter hypothesis that in reality, one is faced with a dynamic competition process, rather than a framework of static optimization. Because firms are "… currently in a transitional phase of industrial history where companies are still inexperienced in dealing creatively with environmental issues (Porter & van der Linde 1995, p. 99)", this implies incomplete information and organizational inertia and as a result of this the possibility of new technological opportunities. In such a situation properly designed regulation can have an influence on the direction of innovation in that (Porter & van der Linde 1995, p. 99-100):

- it signals to firms resource inefficiencies and possibilities for technological improvement;
- if focused on information provision, it can increase firms' awareness for improvement potentials (such as e.g. the U.S. Toxic Release Inventory, the United Kingdom of Great Britain (UK) Pollution Inventory, or the soon mandatory systems under the European Union's Integrated Pollution Prevention and Control (IPPC) regulations);
- it reduces the uncertainty of net paybacks from investments;

- it "… motivates innovation and progress (Porter & van der Linde 1995, p. 100)[7]";
- it provides a 'level playing field' and is necessary in situations with incomplete offsets.

The concept of offsets is central to the argument behind the Porter hypothesis. Innovation offsets can either be product offsets or process offsets. In the former case, these refer to products with better (environmental) performance or higher quality, or to lower product costs or safer products. This form of offsets is based on innovations, which at the same time reduce the environmental impacts of a product and increase its performance or production processes.

Opposed to this, process offsets lead to increased resource productivity and are mostly linked to reduced compliance cost. The argument then is that stringent regulation leads to greater innovation than lax regulation, since the latter can often be addressed by 'end-of-pipe' pollution control[8] and secondary treatment equipment. Stringent regulation may increase compliance costs, but "while the potential for innovation offsets may rise even faster .. the *net* cost of compliance can fall with stringency and may even turn into a net benefit (Porter & van der Linde 1995, p. 100)".

5.3 Formal models analysing the Porter hypothesis

A number of formal models have been proposed to make possible or to show the limitations of the Porter hypothesis. These shall be briefly reviewed in the following with regard to their structure and main results before a synthesis on the theoretical knowledge about the Porter hypothesis is attempted in the final section of Chapter 4.

Sinclair-Desgagné and Gabel provide a theoretical analysis (Sinclair-Desgagné 1999; Gabel & Sinclair-Desgagné 2001; 1993) in which they suggest for environmental regulation to be considered "… an industrial policy instrument aimed at increasing the competitiveness of firms, the underlying rationale for this statement being that well-designed environmental regulation could force firms to seek innovations that would turn out to be both privately and socially profitable (Sinclair-Desgagné 1999, p. 2)". The argument made is

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[7] By this Porter and van der Linde mean that regulations (next to competitors, customers and changes in relative prices for factor inputs) have a pivotal function in giving external input to a firm to motivate and trigger innovation processes.

[8] Pollution control is one of the earliest strategies adopted by businesses to meet the requirements of newly emerging environmental legislation and emission limits. It assumes fixed production processes and product designs and consequently solutions focused on 'end-of-pipe' technologies involving environmental investments that represented high extra costs for firms (Porter & van der Linde 1995; Cohen et. al. 1995). The most visible artifact of the pollution control approach is probably flue-gas de-sulphurisation technology used to abate sulphur dioxide (SO_2) emissions from power stations. Interestingly, pollution control expenditures developed into a measure of environmental performance/regulatory burden (Cohen et. al. 1995) which is comparable to the use of GDP as a welfare measure i.e. it is assessing the effort to achieve an objective rather than the objective itself. Pollution control as an environmental strategy can be characterised by compliance with all environmental, health and safety regulations (Fava & Smith 1998) and can be considered the minimum level of environmental strategy a firm can adopt without pursuing illegal activities. Pursuing pollution control as a corporate environmental strategy involves the use of expensive and non-productive investments in pollution control equipment and only leads to compliance with existing regulations (Hart & Ahuja 1996). It therefore reduces earnings (due to high expenditure and low cost savings and revenues) but also environmental risks and is often considered a necessary expense for continuing operations and protecting the value of a firm's assets including brands and other intangible assets (Reed 1998).

that that the interaction between environmental regulatory policy and the allocation of resources is complex, multi-step, and imperfect (Gabel & Sinclair-Desgangé 2001), for which a number of reasons are cited, the first of which is that it would be "… inconsistent, albeit convenient, to assume that markets are flawed but that firms are perfect (Gabel & Sinclair-Desgangé 2001, p. 149)" and that organizational failures which "… are analogous in many respects to the problems of externalities in … market-mediated transactions (Gabel & Sinclair-Desgagné 2001, p. 150)" are of importance here because they "… are relevant to the firm's management as well … since their manifestation is frequently unachieved profit potential (Gabel & Sinclair-Desgagné 2001, p. 150)".

A second point is that organisational failures are necessary for the existence of innovations that simultaneously improve environmental performance and economic competitiveness of firms. Despite of this, "standard neoclassical-economics models .. do not support the systematic presence of low-hanging fruits (Sinclair-Desgagné 1999, p. 3)" because in these models ".. innovation itself is not free, and if one prices managerial time and all other inputs correctly at their opportunity costs, it should become clear that putting stronger environmental requirements on polluting firms generally increases their production cost more than their revenue (Sinclair-Desgagné 1999, p. 2)". Increases in production costs should have an observable effect on a firm's profitability. The existence of cheap innovations ".. is logically most likely in situations where the firm is far from the efficiency frontier, where the burden of the compliance cost is light, and where the shift to the frontier can be made cheaply (Gabel & Sinclair-Desgangé 2001, p. 152)".

These considerations of Sinclair-Desgangé and Gabel support one important aspect of the Porter hypothesis, namely inefficiencies within firms which are revealed under stringent regulations. If such organisational failures are systematically caused by perverse incentives, imperfect information, moral hazard, hidden actions or strategic behaviour then this renders credit to the mechanism behind the Porter hypothesis, namely the discovery of win-win-opportunities for innovation, even if those already existed prior to any regulation. Given that firm-internal, (quasi-regulatory) instruments exist to address such failures, including contract design, centralization and decentralization of authority, task allocation decisions, accounting systems and monitoring technologies (Gabel & Sinclair-Desgagné 2001) it seems an important research question which type of government policy is most supportive to rectify organizational failures.[9]

Lankoski (2000) analyses a model with vertical product differentiation[10] in a duopoly. In such a model, environmental performance can be understood as a quality variable, assuming that its improvement does not imply any trade-offs. Assuming two firms - one supplying a product with high and another supplying one with low environmental performance – and consumers with a willingness to pay for environmental performance greater than

[9] The basic argument nevertheless remains the X-efficiency argument that external shocks caused by stringent environmental regulations may reduce inefficiencies and failure within the firm (Xepapadeas & de Zeeuw 1999).

[10] Product differentiation refers to the degree to which products are perceived differently by buyers, measured e.g. through the cross-price elasticity of demand (Moschandreas 1994).

zero, the model analyses outcomes based on full and incomplete market coverage. The formal analysis of the model reveals that in a duopoly where firms engage in a two-stage game (first choosing environmental performance levels and than either (in case of Bertrand competition) prices or (in case of Cournot competition) quantities) firms always supply products with different environmental performance levels.

According to Lankoski (2000) the implication of this is that the link between environmental regulation and competitiveness is not uniform in cases where firms' choices are not independent of one another. In particular, the selected environmental performance levels may not be socially optimal, thus justifying regulatory intervention. This provides an indication that the validity of the Porter hypothesis may crucially depend on specific circumstances, like e.g. the industry's market structure.[11]

Xepapadeas and de Zeeuw (1999) in their model show that downsizing and modernization in firms subjected to stringent environmental regulations increases their average profitability, thus having a positive effect on the marginal change of profitability and environmental performance.[12] Doubting the general validity of the Porter hypothesis they nevertheless acknowledge that in strategic trade models "… it is possible to construct specific examples in which foreign R&D decreases and home profits increase under an environmental tax (Xepapadeas & de Zeeuw 1999, p. 166)". Their starting point is however a different one in that Xepapadeas and de Zeeuw analyse in their model the reaction of firms in terms of the type and the quantity of equipment that firms invest in as a response to production cost changes. They show that the increase in production costs from stringent environmental regulations leads to a capital stock restructuring which in turn increases the average productivity of firms. At the same time, in their model (in which firms invest in

[11] For example, general product differentiation may be a precondition for successful environmental product differentiation in a market. Further necessary preconditions can then be derived from a more detailed analysis of the factors influencing specifically environmental product differentiation. Alanen (1998) suggests that if a product has a low own-price elasticity of demand, bundles environmental goods with private goods and provides scope for environmental image and content differentiation then the likelihood is higher for a win-win situation between social and private welfare. The own-price elasticity of demand is depending on availability of substitutes, presence of switching costs for customers and the degree of price-based competition in the market, in relation to the level of competition based on differentiation. Environmental content differentiation refers to the benefit from the product for the customer and is possible, if the public good of improved environmental performance can be combined with a private good (i.e. a product attribute, e.g. price or quality, which is of benefit exclusively for the individual customer purchasing the good) in one product. Environmental image differentiation refers to the ability of a product to communicate information about the purchaser to him-/herself or others. Together, the scope for environmental content and image differentiation determine the customer's willingness to pay for environmental differentiation which refers to the importance customers give to communicated environmental performance in their buying decisions (Alanen 1998). Willingness to pay, together with customer perception of environmental differentiation (which results from the communicated environmental performance of a company) determine the ultimate private benefits of the purchasing customers. Therefore the potential for successful environmental product differentiation depends on three necessary pre-conditions, which are together also sufficient (Reinhardt 1999, pp.151-152): (i) customer willingness to pay for environmental differentiation (implying a high level of general product differentiation), (ii) information about the environmental and private benefits conferred by the product, and (iii) inability of competitors to replicate environmental product differentiation.

[12] Their starting point is (as is for many others) that competitiveness (here understood as changes in trade and investment patterns) is empirically not much affected by stringent environmental regulation. They acknowledge however, that the ability to empirically measure the stringency of regulation is limited due to compliance costs only being a small fraction of total production costs, relatively small stringency differentials between countries and because often investments are made in state-of-art technology regardless of the regulation level required (Xepapadeas & de Zeeuw 1999).

equipment of different ages) stricter environmental regulations (modeled in terms of an increase in an emission tax) result in a reduction of the amount of equipment of all ages and thus a reduction of firm size, which they refer to as a 'downsizing' effect. This effect refers to a reduction in total capital stock and together with a 'modernization' effect (which reduces the capital stock's average age by accelerating the removal of older equipment) leads to the conclusion that it "… is not that a win-win situation can be expected, but the trade-off between improving the environment and the competitiveness of the home industry is not as grim as it is sometimes suggested because of favourable change in the composition of capital stock (Xepapadeas & de Zeeuw 1999, p. 167)".

The model reveals that the additional cost of more stringent regulation are mitigated by the 'downsizing' effect (leading to upward pressure on prices), the 'modernization' effect (increasing the capital stock productivity), and the joint effect of both (allowing to reach an emission target with a lower tax level). The model shows further that the marginal decrease in profitability is lower and the marginal decrease in emissions higher in a situation with heterogeneous capital (in which both downsizing and modernizing occur) compared to a situation with homogeneous capital (in which only downsizing is possible) and that any effects are only affecting those ages of the capital stock on which the higher tax level is levied (Xepapadeas & de Zeeuw 1999). In summary therefore, the model of Xepapadeas and de Zeeuw (1999) remains somewhat skeptical about the Porter hypothesis in that it questions the necessity of stringent regulation for the realization of existing win-win opportunities (better environmental performance and reduced production costs or innovation offsets in excess of the additional costs of regulation) but also shows that trade-offs between environmental quality and competitiveness may be less pronounced than commonly thought, thus explaining at least in part the empirical finding of insignificant links between regulation and competitiveness.

Simpson & Bradford III (1996) provide an early theoretical argument, why the Porter hypothesis that stringent environmental regulation leads to improved industrial performance because it induces innovation and higher resource efficiency is likely not the usual case. They state that "… it is by no means clear that the benefits will repay the investment in the necessary innovation (Simpson & Bradford III 1996, p. 283)" with "… innovation as the mechanism by which stringent environmental regulation is translated into long-run competitive advantage (Simpson & Bradford III 1996, p. 283)". Their argument is based on the assumption that increased competitiveness of firms is the result of reduced marginal costs. According to them the direct effect of regulation is to increase costs, and only the indirect effect would be reduced variable (and thus marginal) costs through innovation. In their model, they "… suppose that the government's objective is to maximize a domestic firm's profits net of the (presumed) environmental externalities it imposes (Simpson & Bradford III 1996, p. 283)". The benchmark here is a Pigouvian tax and the question is whether it is optimal to apply an effluent tax lower or higher than the marginal damage caused by an industry. To analyse this question, a model is used with a Cournot duopoly involving a domestic and a foreign firm in which "… the domestic government tries to create an advantage for a domestic firm selling in a foreign market (Simpson & Bradford III 1996, p. 284)" with the government policy being represented by an effluent tax.

The main finding of the model is that whilst ".. it is possible to develop a model in which effluent taxes in excess of marginal external damages are optimal (Simpson & Bradford III 1996, p. 284)" this is not an easy task so that stringent regulations induce innovation only in very special cases and are thus unlikely to generate broad advantages because of complex interactions making likely differences across industry sectors. Hence, ".. even if tougher environmental regulations did serve to enhance competitive advantage, the same objective might be achieved more effectively by more direct and conventional policies (Simpson & Bradford III 1996, p. 284)", and therefore "…tightening regulation to induce advantage may be extremely dubious as practical policy advice (Simpson & Bradford III 1996, p. 284)". In addition to these conclusions, Simpson and Bradford III (1996) find in their model, that the optimality of taxes in excess of marginal damages depends also on international spillovers of innovation expenditures and on innovatory activities of foreign firms as a response on domestic environmental policy-making, which cannot be predicted with high generality and precision. The results in their simple model thus "… cast serious doubts on the efficacy of environmental policy as industrial policy (Simpson & Bradford III 1996, p. 285)" increasing the competitiveness of domestic firms through innovation induced by environmental policy making.

Alpay (2001) compares the model with effluent tax analysed by Simpson and Bradford III (1996) with a model based on a tradable emission permit system. In his model, two symmetric firms competing in a Cournot oligopoly in each of two countries are analysed. The firms, which all have identical marginal costs, produce one (perfectly substitutable) good generating emissions assumed to be proportional to the output of the firms. Next to reducing output, abatement is possible for each firm to reduce emissions, with the abatement cost function being convex in abatement (Alpay 2001). To regulate the firms in the two countries, a tradable emission permit system is used which is applied to all firms. Initially, all firms are assigned the same identical amounts of tradable permits and the market for permits (which can be sold at a positive price, if a firm's permit demand is smaller than its initial endowment) is perfectly competitive. Solving the firms' optimization problems in the equilibrium by deriving the first order conditions results in the firm-specific reaction functions.

Alpay (2001) assumes a model, in which after distributing an initial amount of permits, one country puts more stringent regulation in place by reducing the number of permits, whilst the other country does not change its regulation. Firms in the former country may carry out R&D (at positive cost) to develop (with a defined success probability) a new production/abatement technology (resulting in reduced emissions), or they may continue to use the existing technology. Four cases can now be distinguished as outcomes of the model. Firstly, if both firms continue with their existing technologies, then "stricter regulations at home country will make foreign firms better-off unconditionally; however, due to changes in permit prices, it is not always true that domestic regulations will make domestic firms less competitive than foreign firms (Alpay 2001, p. 13)". Secondly, "when environmental regulations become more stringent at home, and domestic firms try to innovate, market share of the domestic firms will increase (Alpay 2001, p. 14)" but only if (in the presence of innovation) the costs of permits per unit of output are lower after regulation have become

more stringent. Also firms in the home country may be more competitive depending on the economic characteristics of the new technology, the costs of R&D, the price elasticity of permit demand, and the success probability of innovation in production/abatement technology (Alpay 2001). “Due to changes in permit prices with the enactment of stricter environmental policies, it is possible that the projects that were not feasible before can become profitable after the introduction of stricter environmental policies (Alpay 2001, p. 15)” because stricter regulation increases the price of permits and therefore the possibility of higher permit revenues, which may increase returns on innovation thus making additional innovations profitable.

Finally, Alpay (2001, p. 17) finds that “when environmental regulation becomes more stringent at home, and only one domestic firm innovates, market share of the non-innovating domestic firm will be less than the shares of the all [sic, M.W.] other firms”. In this situation, the competitiveness of the domestic firm may rise relative to that of the other firms, depending on whether the cost of R&D are smaller than the benefits which depend on changes in abatement technology through innovation and changes in the permit market, and the probability of successful innovation. Overall, Alpay’s (2001) analysis indicates stronger pro-revisionist theoretical evidence than previous formal models with the key feature being that the profits of a firm depend on permit revenues and hence permit market properties. This also means that it is not necessary to assume X-inefficiency (Sinclair-Desgagné 1999, Gabel & Sinclair-Desgangé 2001) for the Porter hypothesis to be valid.

Mohr (2002) uses a model similar to that of Xepapadeas and de Zeeuw (1999) and additionally assumes external economies of scale (i.e. spillover) in production, thus allowing that productivity depends on the cumulative experience with a technology. Based on a general equilibrium model of a closed economy with many agents, constant population, perfect information and an environmental externality he shows that whilst “... environmental policy simultaneously increases productivity and welfare (Mohr 2002, p. 159)”, “… a policy that produces this result is not necessarily optimal (Mohr 2002, p. 159)”. Mohr (2002) shows that in his model, environmental regulation (in form of a tax) increases productivity and reduces the environmental externality if (i) an unused technology is available, which is always more efficient than the one currently used and (ii) if environmental policy favors the unused but more efficient technology. Therefore “Porter’s hypothesis is a plausible outcome if one allows for the possibility of technological change with external economies of scale (Mohr 2002, p. 164)” but “.. does not, however, imply that government should pick policies that raise output and reduce pollution (Mohr 2002, p. 164)” since “…. it is quite possible that the optimal adoption of cleaner technology would result in both more output and more waste (Mohr 2002, p. 164)”. This is because if the unused technology is more efficient, then the opportunity cost of abatement increases and (assuming a constant marginal disutility of pollution) it would be optimal for government to allow an increase in pollution/waste.

Along the way, Mohr (2002) notes that interestingly, the Porter hypothesis is similar to the infant industry argument, which is consistent with economic theory and hence it may not be surprising, that this can also be the case for Porter’s hypothesis. Mohr (2002) con-

cludes on the basis of this that similar to those reasons that hinder the implementation of the infant-industry argument as a trade policy, problems with implementing the Porter hypothesis, despite of its validity, may outweigh its potential benefits.

5.4 Conclusions from the theoretical analysis of the Porter hypothesis

With regard to theoretical reasoning about the Porter hypothesis that strict environmental regulations translate into a long-run competitive advantage of national industries (and the basic argument made that, although regulations have an economic cost, properly constructed environmental standards may, whilst imposing costs, spur innovations which offset some or all of the spending on pollution abatement) the evidence is mixed. Whilst there is evidence in formal models that environmental protection is not a perfect zero-sum game, and that integrated regulatory systems (Esty 1994) are able to bring about 'double dividends' this does not have to be economically efficient. Even if regulation leads to innovation offsets, which reduce the cost of compliance and produce competitive advantages for products and production processes, and simultaneously increase social welfare by reducing environmental externalities, this may not be an optimal choice.

As conditions, under which a favourable relationship between environmental regulation and competitiveness, the following points emerge from a comparative analysis of the different models discussed:

- the use of economically efficient types of regulation, in particular tradable permits;
- a favourable market structure[13]; in particular demand for environmentally differentiated goods by a sufficiently high number of consumers;
- the availability of unused technologies wit higher efficiency;
- downsizing and capital modernization make trade-offs less grim.

[13] According to Bain (1959), market structure can be defined as a set of organizational features of a market, which have a significant influence on the nature of competition in this market.

6 EMPIRICAL ANALYSIS OF THE PORTER HYPOTHESIS

6.1 Introduction

Whilst Porter and colleagues in their work provide some empirical evidence, they mainly focus on case studies, based on the argument that these "… are the only vehicle currently available to measure compliance costs and both direct and indirect innovation benefits (Porter & van der Linde 1995, p. 101". Whilst this was true at the time, even then already reviews of broad-based econometric empirical studies existed (e.g. Jaffe et al. 1995). Subsequently, more broad-based empirical work was reported (e.g. Albrecht 1998a; 1998b; Mulatu et al. 2001; Murty & Kumar 2003). However the basic argument concerning compliance costs is still valid in some ways (see e.g. Jaffe et al. 1995).[14]

[14] The argument about compliance cost measurement rests very much on the on-going environmental accounting debate. Environmental accounting at the firm level can be used in the contexts of financial or management accounting. In the first context it is addressing an external audience and is aimed at the estimation and public reporting of environmental liabilities and financially material environmental costs. In the context of management accounting, which uses a broad range of cost and performance data for internal decision-making, the aim is to integrate environmental accounting into cost allocation, capital budgeting and process/product design procedures (EPA 1995). Of particular relevance here are environmental costs and investments. Environmental costs refer to running costs that occur permanently over a production period. Running costs can be direct production costs or overheads. Environmental investments refer to costs that occur at one specific point in time. Such costs can be split up in direct investment costs (e.g. costs of plant & equipment) and overheads (e.g. interest payable for capital). Environmental costs can be further divided into conventional, direct costs and indirect costs. The latter group can be further subdivided into hidden or potentially hidden, contingent (i.e. liability) and image and relationship (i.e. less tangible) costs (EPA 1989; GEMI 1994). Conventional (environmental) costs (e.g. direct and indirect materials and labour or technical, sales and general administrative overheads) are addressed in cost accounting and capital budgeting, but are not usually perceived as environmental costs. Hidden or potentially hidden costs refer to up-front, operational and back-end costs incurred when complying with legislation or when improving environmental performance voluntarily beyond compliance (see Jaffe et al. 1995, pp. 139-142 for a detailed discussion). Such costs may be related to the clean-up of past pollution unrelated to current operations, to pollution control, clean-up or pollution prevention or reduction in current operations or to pollution prevention or reduction in future operations. Contingent environmental costs or benefits are costs or benefits that may be incurred or realized with a certain probability and a certain expected value at some point in the future. They represent less tangible or intangible environmental costs where direct benefits resulting from expenses to improve a firm's corporate image or the subjective perception of its stakeholder relationships are difficult to monetarise (EPA 1995). Most commonly known environmental costs are costs of environmental remediation, expenditure on pollution control equipment, spending on non-compliance penalties and costs incurred for pollution prevention activities beyond required compliance levels. These most common environmental costs could be termed direct environmental costs and can be defined as environmental costs that are addressed in accounting as compliance costs.
With regard to environmental investments, investment decision generally mean that a firm makes a cash outlay with the aim of receiving in return future cash inflows. Investment decisions are usually part of a firm's investment strategy, which is formalized in its capital expenditure plans (Lumby 1991). The planned capital expenditures of a firm are part of its capital budgeting process and entail comparisons between predicted costs and revenues using different investment appraisal methods (e.g. payback, net present value, internal rate of return or return on capital employed). Traditional investment appraisal techniques usually exclude environmental costs, savings and revenues, but several new approaches have been proposed to incorporate these (EPA 1992; Earl 1996). In order to fully consider environmental costs, cost savings and revenues generated by different environmental investments and the potential but less tangible benefits of such investments have to be evaluated, if necessary through non-monetary valuation of environmental effects. Issues and steps in this respect are the full identification of potential costs and savings from an investment in environmental improvement, appropriate allocation of costs and benefits, appropriate indicators and methods for project appraisal and suitable payback time horizons. Potential less tangible benefits of pollution prevention or other environmental investments have been identified (EPA 1995), including increased product sales leading to increased revenues and profits, better borrowing conditions for capital (i.e. lower interest rates and risk premiums), improved market performance, e.g. higher share prices, cost savings from reduced inputs, improved health and safety and more efficient processes, increased labour pro-

6.2 Empirical studies addressing the Porter hypothesis

Porter and van der Linde (1995) in their initial study of the Porter hypothesis cite several case studies as evidence for the validity of the Porter hypothesis. This concerns e.g. the cell battery, printing ink, electronics manufacturing, pulp and paper and refrigerator industries. According to them, case study evidence from primary research and analysis of published case study material supports a number of mechanisms through which the Porter hypothesis is put to work. This concerns e.g. substitution with cheaper materials and better process efficiency in materials utilization as well as premium prices and new markets for more environmentally sound products. Porter and van der Linde (1995) criticize that compliance cost estimates in econometric studies are overestimated because they assume away innovation benefits. Also such studies according to them do not sufficiently take into account the initial level of competitiveness in an industry. Porter and van der Linde (1995) also argue, that (in 1995) the large majority of studies did not reveal many adverse effects of environmental regulation on competitiveness and that those studies finding significant effects often used compliance cost estimates based on existing (inefficient) regulation that likely stifle many innovation offsets. This is an important issue, since any falsification of the Porter hypothesis based on regulation identified in Chapter 2 as being not economically efficient (e.g. standards based on emission limits) can not be regarded as evidence against the hypothesis (see Romstad (1998) and Chapter 2.2 for a more detailed discussion). This is because inefficient regulation increases compliance costs, thus making it less likely for innovation benefits to offset costs, i.e. such regulation introduces a systematic bias in empirical studies. Therefore, strictly speaking the Porter hypothesis can only be tested under regulation that has been shown to be economically efficient (such as systems based on taxes or certificates, see Chapter 2). Porter and van der Linde (1995) discuss in detail characteristics of efficient regulation, such as e.g. clear goals, flexible approaches, incentives for innovation and regulatory coordination.

Jaffe et al. (1995) review 16 empirical studies on the effects of environmental regulation on competitiveness with particular focus on the U.S., and limited to manufacturing firms. Whilst pointing out, that direct compliance costs are only a fraction of the total social costs of environmental regulation, they conclude that ".. there is relatively little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness, however that elusive term is defined (Jaffe et al. 1995, p. 157)". In their survey, they analyse studies using many of the different measures of competitiveness discussed in Chapter 3 (net exports, overall trade flows, plant location decisions). Jaffe et al. (1995) also acknowledge data problems as a serious impediment to more conclusive results. They discuss as well a sub-set of studies analyzing the productivity effects of regulation, which is most relevant to the propositions of the Porter hypothesis. Here, the finding is that for the period 1970-80, total factor productivity growth in the U.S. is esti-

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ductivity due to higher employee motivation and efficiency, better relationships with regulators, especially easier approvals of expansion plans, and reduced costs due to improved corporate image and relationships with stakeholders. Measurement of these types of compliance costs is very complex and this is why Porter and van der Linde argue, that it can only be done on a case study basis focusing on one or few firms.

mated to decline by 8-16 percent due to increased regulatory costs, which means that these are not main drivers for productivity losses.[15]

Jaffe et al. (1995) note that average productivity in individual industries could in theory increase (and not decrease) if more stringent regulation forces the most inefficient plants to close but have doubt that "… continually higher regulatory standards would lead firms regularly to discover new clean and profitable technologies (p. 156)" and note that (in 1995) "systematic empirical evidence in this area is only beginning (p. 157)".

Since the aggregated effect for the manufacturing industry of a country (measured e.g. in terms of industry (FDI) migration or changes in trade patterns) is constituted of the individual changes in each of the constituting industries, it is necessary to identify more precisely conditions and parameters for an industry to profit or dis-benefit from stringent regulation. For example, Albrecht (1998a; 1998b) has focused his analysis on specific industries/products (here refrigerators, freezers, air conditioning equipment, fire extinguishers, foams, aerosols and solvents for cleaning of electronic equipment) affected by the Montreal Protocol on Ozone-Depleting Substances and provides evidence in two countries (U.S. and Denmark) that their competitive position was enhanced by stringent regulation. He argues that for each product a country exports the compliance and environmental costs caused by (more) stringent regulation will differ and that this is masked if industry total figures are used, which usually refer to a large number of products. The Montreal Protocol is identified as particularly suitable for a product-specific test of the Porter hypothesis, since the corresponding regulations have been implemented almost simultaneously in different countries with very similar objectives (phase-out of chlorofluorocarbons, CFC) without exemption of a significant number of firms. For example, due to the Protocol, all countries face the same technological substitution costs. Albrecht (1998b) analyses empirically, if the competitiveness of the main CFC-using manufacturers in the U.S. and Denmark has increased after the implementation of the Montreal Protocol by investigating changes in trade flows for the three most relevant industry sectors in 1989-95. The dependent variable for this analysis was the change in bilateral exports for the country of origin and the independent variables the change in bilateral exports which the country of origin imported from the buying countries, the relative change in the bilateral exchange rate and a dummy variable taking unity value for the U.S. and Denmark (as countries with pro-active/stringent environmental regulations) and zero for all other countries (France, Germany and Japan).[16]

The analysis found that the dummy variable for early action in the U.S. and Denmark was significant in regressions pooling all three sectors, as well as in the sector-individual regressions for household refrigerators and freezers and for industrial refrigeration, but not for air conditioning (the possible reason being, that mobile and stationary air conditioning could not be separated in the analysis). Albrecht (1998b) concludes that "… the two coun-

[15] It has to be noted as well, that in the period when effects were observed only limited incentive-based/market-based regulation (e.g. taxes or certificates, see Chapter 2) existed.

[16] Due to data unavailability, no other variables, such as labour productivity or wage rates were included in the analysis.

tries with a relatively active CFC-policy and relatively high CFC-substitution costs could improve their competitiveness and hence export performance (p. 16)", and considers this as more than anecdotal evidence in favour of the Porter hypothesis. According to him, the limited empirical evidence from other surveys addressing the effect of environmental regulation on competitiveness may result from the use of a non-optimal methodology pooling many different industrial sectors and even more products and thus masking any effects in specific industries by aggregation influences.

Mulatu et al. (2001) use the meta-analysis technique, especially meta-regression, to analyse empirical studies on the effect of stringent environmental regulation on international trade in order to establish the conclusiveness of empirical work on this topic.[17] Analysing 13 studies based on the exploratory, Leontief and econometric approaches, they conclude that based on simple-vote counting, a high number of effect estimates are insignificant and that the number of significant negative estimates is considerably higher than that of positive ones, thus casting doubt on the empirical validity of the Porter hypothesis as concerns international trade. However, Mulatu et al. (2001) find that votes differ depending on the method used to estimate effect sizes. For example, differences in means lead to many significant negative estimates, whereas correlation coefficients are either insignificant or significantly positive. Using a number of different statistical methods for combining significance levels (minimum-p, sum of z's, sum of logs and Logit), the authors find "… that for all types of studies all four methods almost always reject the null hypothesis that the relationship between environmental stringency and trade performance is not significantly different from zero (Mulatu et al. 2001, p. 17)". This means, that for the type of studies analysed, a significant (positive or negative) effect should exist.

In the final part of their study, Mulatu et al. (2001) in a meta-regression analysis estimate based on an ordered Probit model the effects of a number of methodological factors on the (differing) results of primary studies analyzing the effect of stringent environmental regulations on international trade. Such factors include whether a Heckscher-Ohlin model or the gravity model was used, if the study used the exploratory, Leontief or econometric approach, whether the studies reported dollar values, elasticities or other data, if the stringency of regulation was assessed by means of abatement costs, a categorical stringency index, or qualitative measures, whether multi- or bilateral trade flows were considered, if time series data of industries, cross-sectional data of industries or countries, or industry or country panel data were used, which year the effect size estimates referred to, what time period was covered, and what the ratio of the number of less developed to developed countries in a study was. Mulatu et al. (2001) find that econometric studies (rather than exploratory and Leontief studies), the presence of less developed countries in the sample and application of the gravity model as well as studies analyzing more recent data yield significantly less negative results. Also, if stringency is measured by a qualitative or cate-

[17] Meta-analysis (considered to be more reliable than vote-counting used commonly in literature surveys) assumes that existing empirical studies on a specific topic are drawn from the universe of perceivable studies and statistically interferes from the sample of studies to the conclusiveness of empirical evidence in general for the topic in question, whilst controlling for influences of research designs, data quality etc. (Hedges & Olkin 1985).

gorical index, significantly more negative results are found, confirming the measurement debate surrounding stringency and the need to address this issue. Significantly more negative results are also found, if sectoral instead of country data is analysed, if cross-section and panel data instead of time-series data are studied, trade flows are measured bilaterally, Ordinary Least Squares (OLS) is the estimation procedure chosen and when including pollution intensive industries. Overall, Mulatu et al. (2001) conclude "… that the empirical literature does not strongly support the hypothesis, that the effect of environmental regulation on competitiveness is negative (p. 22)", but at the same time reject the hypothesis that there is no significant effect in almost all cases. The suggest that "the environmental regulation-competitiveness linkage should be investigated with data on the industrial level … (Mulatu et al. 2001, p.23)" as e.g. done by Albrecht (1998a; 1998b) due to regulation being industry-specific and that better stringency measures should be used.

The study by Murty and Kumar (2003) analyses the influence of environmental regulation on the productive efficiency of 92 firms in 12 water-polluting industries in India for the period 1996-1999 based on simultaneous estimation of the causal link between technical inefficiency and environmental regulation and the stochastic output distance function using the maximum likelihood method. Date is based on a primary survey and covers wastewater amounts, loads of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Suspended Solids (SS) loads as well as sales as outputs and wage bills, capital stock and monetary value of materials as inputs. From these data, a regulation index defined as the geometric mean of the three normalized measures of BOD, COD and SS each normalized by scaling down each observation by the respective maximum across all years. The index is used as a measure for firm compliance (the higher the value the lower compliance). Also, a conservation index is defined as the ratio of wastewater to sales. Estimation of the relevant parameters of the output and input functions reveals that most parameters are significant and that technical inefficiency is no linear function of the regulation index, conservation index and the time variable, respectively. The former two variables are found to be significant whereas the latter is not. Also, the analysis reveals, that the determinants of inefficiency account for the majority of the variation of technical inefficiency. Murty and Kumar (2003) furthermore find that the higher is firms' compliance, and the lower wastewater output per unit of sales is, the lower is the technical inefficiency of the firm, thus lending support to the Porter hypothesis.

6.3 Conclusions from comparing empirical work on the Porter hypothesis

The comparison of empirical studies testing the Porter hypothesis reveals, that several levels need to be distinguished, to which the Porter hypothesis can be applied. This concerns at least the firm, industry, country levels. Depending on which level is the focus of analysis results may differ. Also, comparison of studies is hindered by the use of different measures for competitiveness and stringency of environmental regulation. In particular measurement of the latter seems to be particular difficult (in the absence of undisputed definitions) yet at the same time crucial for the interpretation of results from empirical studies, which overall indicate a small positive effect.

7 COMPARISON AND CONCLUSIONS

7.1 Introduction

This final chapter will analyse comparatively the theoretical arguments and models and empirical studies on the Porter hypothesis and will discuss implications for policy making and future research. It will also, as far as possible, attempt to define more precisely conditions, which support the Porter hypothesis. Here, particular focus will be placed on critical aspects that have emerged during the analysis of theoretical reasoning and empirical work on the Porter hypothesis. Especially, these concern measuring stringency of and approach to environmental regulation, the level at which the Porter hypothesis is analysed, and the role of innovations.

7.2 A comparative analysis of findings on the Porter hypothesis

A comparative analysis of the Porter hypothesis can be done between different theoretical models, between different empirical studies, between theoretical and empirical work and between different interpretations and levels of analysis of the Porter hypothesis. For theoretical models it is found that:

- there are factors to do with capital structure that make the trade-offs implied by critics of the Porter hypothesis less strong and thus the hypothesis more likely to hold (Xepapadeas & de Zeeuw 1999);
- a favourable demand side can make the Porter hypothesis more likely to hold (Alanen 1998; Reinhard 1999; Lankoski 2000);
- specific (more flexible) types of instruments for environmental regulation (in particular tradable permit systems) bring about more favourable conditions and thus make it more likely for the Porter hypothesis to hold (Alpay 2001);
- conditions under which the Porter hypothesis holds seem to be depending on the pollutants concerned, i.e. the hypothesis is likely to hold more strongly for some pollutants than for others.

Concerning empirical work, the consensus emerging (Portney 2002 quoted in Anonymous 2002) is that the negative macroeconomic impact of environmental regulation is likely small, since the latter empirically leads to both, increasing or decreasing employment (see e.g. Rennings et al. 2001; Morgenstern et al. 2002), depending on the specific conditions. Also environmental regulation empirically led to only very small increases of the rate of inflation and therefore was not the prime cause for negative economic effects.[18] The analysis of reduced compliance costs on employment, GDP growth rates and productivity show empirically only small effects and thus environmental regulation is generally sociable with

[18] It has to be noted that these conclusions mainly apply to the U.S. and developing countries and do not take into account transfer effects. Eliste and Fredriksson (2002) provide a detailed discussion of transfer effects on trade flows.

economic growth. Nevertheless trade-offs exist resulting from higher expenditure caused by more stringent environmental regulation which substitutes spending that would otherwise lead to an increase in measured GDP, since simultaneous spending on both is impossible. In conclusion, empirical research to date makes it thus likely that although Porter's hypothesis may hold in individual industrial sectors or for more narrow interpretations in specific countries under certain regulatory conditions. It is unlikely to hold (empirically as well as theoretically) in its most general form across all levels of analysis and forms of interpretation of the hypothesis, which will be discussed in more detail in Chapter 4.4.[19]

7.3 Measuring the stringency of and approach to environmental regulation

As can be seen from empirical studies, it is of pivotal importance to carefully address the measurement of regulatory stringency. As Mulatu et al. (2001) have shown, the choice of stringency measures has in many cases a significant influence on the results of empirical research. Romstad (1998) points out that from a theoretical viewpoint, it is absolutely indispensable, that any study actually ensures that the regulatory system analysed empirically is economically efficient in the sense discussed in Chapter 2.1. Otherwise a rejection of the Porter hypothesis cannot be taken as such, since additional costs of inefficient regulation would have to be taken into account.[20] It seems likely, that in most countries analysed in empirical studies there is at least some economic inefficiency in environmental regulations. For example, in Germany environmental regulation has a long tradition of 'command-and-control' legislation and thus in many instances cannot be assumed efficient and this is also the case in other countries (Jaffe et al. 1995; Brännlund et al. 1995; Hahn 1989). In addition to this, of the multitude of instruments for environmental regulation discussed in Chapter 2.1, only a subset has been applied in practice. For example, tradable emission permit systems have only become relevant (except for regionally limited applications in the U.S.) for environmental policy making since the Kyoto protocol is on the agenda, even though due to the current status of non-ratification of the protocol, they have been implemented scarcely, so far. One of the few examples is the emissions trading system for greenhouse gases now adopted and in the process of implementation for the EU. Because of this situation, only very limited empirical work has been analyzing regulatory regimes predominantly based on tradable permit systems even though Alpay (2001) shows that for these, compared to a tax based system as e.g. the one analysed by Simpson and Bradford III (1996), the mechanisms behind the Porter hypothesis are more likely to work successfully. Finally, it should be a topic for future research to develop a standard measure that (jointly) measures the stringency of and approach to environmental regulation, since both aspects have an effect.

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[19] For example, Xing and Kolstad (2002) find evidence that for highly polluting industries in the U.S. less stringent environmental regulation in host countries is a significant factor determining foreign direct investment of firms from such industries in the host countries.

[20] Total regulatory costs can be broken down into the costs of achieving an emissions standard and the costs resulting from inefficiency of regulation. Assuming globally increasing and converging emission standards for trans-boundary pollutants, the costs of inefficiency become relatively more important (Romstad 1998).

Even though to date, empirical studies have differentiated to a lesser degree than theoretical work and reasoning between the different instruments of environmental policy making discussed in Chapter 2.1, this will beyond doubt change in future with the increasing relevance of taxes, tradable emission permit systems and voluntary initiatives and agreements (such as the environmental management system standards ISO (International Standards Organization) 14001 and EMAS[21]).

7.4 Different interpretations and level of analysis of the Porter hypothesis

One important issue when analyzing empirically the Porter hypothesis is that it can be interpreted in different ways. According to Jaffe et al. (1995) the hypothesis may mean that specific industries will benefit from environmental regulation of their customers, that innovatory activity in specific technology areas will be increased because of environmental regulation, that some companies will benefit from more stringent regulation at the expense of other firms (which would e.g. be the case if inefficient firms in an industry go out of business), that there will be 'early/first mover' advantages for some firms, or that the (net) competitiveness of a whole national economy (across all industries or at least in terms of net changes across all industries) will be increased through stringent regulation (which would be the case if innovation caused by increased stringency of regulation leads to improved environmental quality *and* improved productivity). Another aspect influencing empirical results is therefore at which level the Porter hypothesis is analysed in empirical studies. Given this wide range of interpretations, empirical analyses after 1995 have usually focused on one specific interpretation and have usually not compared the results for different views. It is thus necessary to distinguish precisely between the different possible levels, at which the Porter hypothesis can be analysed. At least, these are the level of the individual firm, the level of an industry and the level of the national economy.

For individual firms, testing of the Porter hypothesis essentially means to analyse the relationship between environmental performance and economic performance, taking into account the type of environmental management a firm uses and its specific regulatory environment. The firm level is the most disaggregated level of analysis for the Porter hypothesis and it is this level, for which Porter and van der Linde (1995) cite numerous case study evidence, since only at this level it is possible to precisely measure full environmental costs and benefits (see Chapter 5.1 for a more detailed discussion on the full measurement of environmental costs and benefits). At the level of individual firms, it needs to be considered as well if all or only a limited group of firms (e.g. only large firms) in an industry benefit from more stringent regulation, since the aggregated effect for an individual industrial sector is constituted of the effect of regulation on the competitiveness and economic performance of each individual firm.

Whilst an analysis at the industry level will mask any differences between individual firms, it is still more disaggregated than an analysis at the national level. As the empirical work of Albrecht (1998a; 1998b) shows, results at the level of individual industries may differ

[21] Eco-Management and Audit Scheme of the EU

considerably from those for whole countries or national economies. Next to one specific industry, it is also possible, to analyse a narrow cluster of (similar) industries. A parameter on which findings critically depend at this (but also at the more aggregated national) level is which industries are included in the (empirical) analysis. For example, for the pulp and paper industry alone, empirical studies provide rather strong evidence that more stringent environmental regulations put firms in the industry at a competitive disadvantage (Brännlund et al. 1995; Barbera & McConnell 1990), whereas including resource-intensive process industries similar to the pulp and paper industry can actually alter results which may in turn be completely different for industries with relatively low energy and resource intensities. The different possible levels of analysis can be found in empirical studies, but are not much differentiated in theoretical reasoning about the Porter hypothesis, which usually focuses on simple models and country-level analysis. In future, a more complex and disaggregated analysis, based on e.g. approaches in industrial economics and industrial organization (Hay & Morris 1991; Schmalensee 1989) as well as more elaborate modeling approaches are desirable to supplement existing work.

7.5 The role of innovations in the Porter hypothesis

Porter and van der Linde (1995) note the particular role of innovations as a mechanism for putting the Porter hypothesis to work. This is because the concept of innovation offsets (i.e. private benefits to firms from innovatory activity triggered by stringent, yet efficient, environmental regulation) is central to the Porter hypothesis. Opponents to this view argue that the existence of profitable or at least cost-effective opportunities (at the firm, industry or national level) to reduce environmental pollution as proposed in the Porter hypothesis are not likely in most industries. In the best case it pays for firms in such industries to pursue emission reductions until they meet their industry's regulatory standards. Over-compliance in these industries is unlikely, since it would only be rational for firms if it can be achieved through cost-effective pollution abatement, which by assumption is not possible here and therefore regulation beyond emission levels corresponding to the private optimum would increase production costs and in turn reduce profitability and competitiveness (Romstad 1998).

Given their pivotal role in the Porter hypothesis, future research on innovation in this context seems to have some merit. It is argued (Anonymous 2002) that the relative influence of innovation drivers such as private investment or government expenditure in R&D, spending for improvement of education systems, regulation or price changes is unclear and that hence innovation policy should focus on realising prices which reflect full social costs, on correcting for external externalities, and on eliminating subsidies. This could be a starting point for future empirical research and theoretical work.

Other aspects of future research may be that environmental regulation in general should be providing incentives for innovation. As can be seen from Table 1 in Chapter 2.1 (which also provides a more detailed discussion) such characteristics mainly apply to (environmental) taxes and certificates (i.e. tradable emission permit systems) which should thus be applied more often in practice if it is wished to create conditions favourable to the Por-

ter hypothesis (Hemmelskamp 1997, see also Montero (2002) for a more detailed analysis of innovation incentives provided by different types of instruments). As is known from innovation theory and regulation theory in general, innovation should also not be focused on specific technologies and take into account the direction of technological progress at least equally to the rate of innovation. Finally, regulation should be close to the end-user of a technology and also consider voluntary agreements as well as standards and labels for environmentally more sound products (see e.g. Hemmelskamp 1999; Jaffe et al. 2002; Teisl et al. 2002; Rennings et al. 2003 for more detailed discussions of specific aspects mentioned here). Despite the limitations of Porter's hypothesis[22], it provides arguments for preferring incentive based regulations over command-and-control type regulation, since the former likely reduce abatement costs. Incentive based regulation, in particular tradable emission permit systems maintain incentives for firms in an industry to reduce emissions through innovation, provide cost effective allocation and abatement solutions and are therefore likely to at least limit reductions in the profitability of firms. Economic efficiency of regulations (see Chapter 2.1) is pivotal here because low cost regulatory approaches are most likely to reduce trade leakages, which have adverse effects on overall social welfare and such approaches can also reduce barriers to international cooperation on trans-boundary pollution (Romstad 1998). In doing so, efficient regulation can indirectly create competitive advantages (or at least reduce competitive disadvantages) for firms competing internationally, since it reduces part of their regulatory costs whilst at the same time having the potential to trigger innovation offsets that at least reduce the costs of regulation.

[22] For Europe, there has been little research on the Porter hypothesis (for exceptions, see e.g. Hitchens 1999; Rennings et al. 2001; 2003) and future empirical should focus here.

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