Does environmental leadership pay off for Swedish industry? - Analyzing the effects of environmental investments on efficiency•

Thomas Broberg[a], Per-Olov Marklund[b], Eva Samakovlis[a], Henrik Hammar[a,c]

• The authors would like to thank Lennart Hjalmarsson, Thomas Forsfält, Maria Vredin Johansson and Göran Östblom for valuable comments. Financial support from The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS) is gratefully acknowledged.

[a] National Institute of Economic Research, Box 3116, SE-103 62 Stockholm.

[b] Centre for Regional Science (CERUM), Umeå University, SE-901 87 Umeå.

[c] Department of Economics, University of Gothenburg, SE-405 30 Gothenburg.

WORKING PAPER NO 119, JUNE 2010

PUBLISHED BY THE NATIONAL INSTITUTE OF ECONOMIC RESEARCH (NIER)

NIER prepares analyses and forecasts of the Swedish and international economy and conducts related research. **NIER** is a government agency accountable to the Ministry of Finance and is financed largely by Swedish government funds. Like other government agencies, **NIER** has an independent status and is responsible for the assessments that it publishes.

The **Working Paper** series consists of publications of research reports and other detailed analyses. The reports may concern macroeconomic issues related to the forecasts of the institute, research in environmental economics, or problems of economic and statistical methods. Some of these reports are published in their final form in this series, whereas others are previews of articles that are subsequently published in international scholarly journals under the heading of **Reprints**. Reports in both of these series can be ordered free of charge. Most publications can also be downloaded directly from the **NIER** home page.

KONJUNKTURINSTITUTET, KUNGSGATAN 12-14, BOX 3116, SE-103 62 STOCKHOLM

TEL: +46 8 453 59 00 FAX: +46 8 453 59 80

E-MAIL: KI@KONJ.SE HOMEPAGE: WWW.KONJ.SE

ISSN 1100-7818

Contents

Summary in Swedish

Konjunkturinstitutet har analyserat om företagens miljöskyddsinvesteringar har en positiv inverkan på industrisektorernas effektivitet, och därmed i förlängningen om det lönar sig att "gå före" i miljöpolitiken. Analysen baseras på internationellt sett unika data på miljöskyddsinvesteringar inom svensk tillverkningsindustri som möjliggör en uppdelning i typ av investeringar (förebyggande eller behandlande) och typ av miljöområde (luft, vatten, avfall, eller övrigt). Resultaten visar att det inte finns något stöd för hypotesen att miljöskyddsinvesteringar har en positiv effekt på företagens effektivitet. Möjliga förklaringar är att: 1) det finns inget samband mellan miljöskyddsinvesteringar och effektivitet; 2) miljöskyddsinvesteringarna är små i relation till de totala kostnaderna och därför är det svårt att statistiskt isolera effekterna av investeringarna; 3) den eventuella effekten av miljöskyddsinvesteringar på effektivitet sker över en längre tidsperiod än vad vi har kunnat analysera.

BAKGRUND

I svensk miljöpolitik väljer man ofta att "gå före" andra länder. Ett syfte är att visa att det går att förena offensiv miljöpolitik med hög ekonomisk tillväxt. För att motivera politiken används argumentet att det stimulerar svenskt näringsliv till teknologisk utveckling och ökad konkurrenskraft, vilket bidrar till ökad ekonomisk tillväxt. Denna argumentation står emellertid inte oemotsagd.

Ett vanligt argument är att ökade miljökrav försämrar produktiviteten och leder till försämrad konkurrenskraft internationellt. Det är framför allt två faktorer som anses bidra till den försämrade konkurrenskraften: dels leder ökade miljökrav direkt till högre produktionskostnader, och därmed lägre produktivitet gentemot konkurrenterna, och dels tränger miljöskyddsinvesteringar undan mer produktiva investeringar, vilket hämmar produktivitetstillväxten.

I början av 1990-talet ifrågasatte Harvardprofessorn Michael Porter det här synsättet genom vad som har kommit att kallas *Porterhypotesen*. Han menar att rätt utformad miljöpolitik leder till högre produktivitet och därför till förbättrad konkurrenskraft. Han hävdar till och med att ett land som för en ambitiös miljöpolitik av "rätt sort" stärker sina konkurrensfördelar i förhållande till andra länder på den internationella marknaden. Den ytterligare ekonomiska tillväxten som blir resultatet kommer därmed att väga upp de investeringskostnader som den tuffa miljöpolitiken initialt medför. Om hypotesen stämmer kan miljöpolitik bedrivas till låga eller inga kostnader. Förutsättningen för att styrmedel ska kunna generera denna utveckling vilar, enligt hypotesen, på att miljöstyrningen utnyttjar marknadens prismekanism. Det innebär att miljöpolitiken ska sträva efter att använda ekonomiska styrmedel såsom skatter och avgifter. Porterhypotesen har tidigare testats på data från olika länder och för olika branscher, utan att man har funnit något generellt stöd för hypotesen.

SYFTE OCH METOD

Syftet är att analysera om miljöskyddsinvesteringar påverkar företagens totala effektivitet i produktionen. Total effektivitet utgörs av komponenterna Management effektivitet och Teknisk effektivitet, och är ett mått på hur mycket ett företag faktiskt producerar i jämförelse med en potentiellt maximal produktion vid en given tidpunkt. Total effektivitet säger därmed något om möjligheterna att öka produktionen, dvs. produktiviteten, utan att det för den skull krävs teknologisk utveckling. Råder Management ineffektivitet finns det potential till att öka produktionen givet de insatsfaktorer (kapital och arbetskraft) och den produktionsteknologi som företaget redan förfogar över. Exempelvis skulle det kunna handla om att effektivisera organisationsstrukturen. Råder Teknisk ineffektivitet finns det potential till att öka produktionen givet insatsfaktorerna genom att investera i en redan utvecklad och effektivare produktionsteknologi.

I den empiriska analysen testas Porterhypotesen på ett nytt sätt. SCB:s undersökning om industrins miljöskyddskostnader möjliggör att data på miljöskyddsinvesteringar kan delas upp på förebyggande och behandlande åtgärder, vilket är unikt inom den internationella forskningen på området.[4] Detta är speciellt relevant, eftersom det är främst de förebyggande åtgärderna som enligt Porterhypotesen leder till stärkt konkurrenskraft. Dessa åtgärder stimulerar i större utsträckning till innovationer med effektivare resursanvändning. Vi kan därmed analysera om företagens effektivitet påverkas olika av investeringar som renar utsläpp jämfört med investeringar som medför renare produktionsprocesser. Vidare betraktas i analysen miljöskyddsinvesteringarna som ett mått på det samlade miljöregleringstrycket.[5] Om denna tolkning av miljöskyddsinvesteringar är rimlig utgör de en del av kostnaden för miljöpolitiken, utöver möjliga kostnader i form av att t ex andra mer produktiva investeringar trängs undan.

Mer konkret genomförs analysen i två steg. Först uppskattas företagens totala effektivitet med en produktionsfunktionsansats och sedan används en modell för att analysera hur den denna effektivitet påverkas av behandlande respektive förebyggande miljöskyddsinvesteringar. Detta sker dels på aggregerad nivå (för Trävaru-, Massa och pappers-, Kemisk-, Gummi och plastvaru- samt Stål och metallindustrierna gemensamt), och dels för de enskilda sektorerna var för sig. Analysen genomförs dessutom med förebyggande och behandlande miljöskyddsinvesteringar uppdelade på olika miljöområden (luft, vatten, avfall och övrigt).

Tabell 1 visar hur miljöskyddsinvesteringarna i vårt urval varierar mellan olika sektorer. Totalt sett utgör miljöskyddsinvesteringarna mindre än 1 procent av industrins rörliga kostnader. Miljöskyddsinvesteringarna är lägre för trävaruindustrin och högre för massa- och pappersindustrin oavsett miljöområde. Tyvärr ingår inte investeringar för att minska koldioxidutsläppen och för att energieffektivisera i SCB:s undersökning om industrins miljöskyddskostnader.

---

[4] Förebyggande investeringar kännetecknas av att: (1) de minskar uppkomsten av utsläpp från själva produktionsprocessen; (2) de möjliggör användning av mindre miljöpåverkande insatsvaror; (3) de medför nya och mindre miljöpåverkande utrustningar och processer. De behandlande investeringarna kännetecknas av att de inte påverkar själva produktionsprocessen. Deras syfte är att ta hand om och behandla utsläppen som företagets verksamhet ger upphov till, förhindra spridandet samt mäta utsläppsnivåerna (SCB, 2004).

[5] I allmänhet kan miljöinvesteringar förklaras av en kombination av regleringar, skatter och avgifter på miljöområdet, samt vara ett uttryck för att företag satsar på att miljöprofilera sig. I föreliggande studie utgår vi ifrån att huvuddelen av miljöinvesteringarna sker på grund av att företagen är tvingade till det.

Tabell Genomsnittliga miljöskyddsinvesteringar för företagen under perioden 1999-2004 (1000 kronor)

Miljöskydds-investering	Trävaru-industrin	Massa och papper	Kemisk industri	Gummi- och plastvaror	Stål och metall
Luft					
Behandlande	126	1 061	866	142	969
Förebyggande	92	2 872	650	50	620
Vatten					
Behandlande	25	5 838	809	46	560
Förebyggande	29	2 978	133	15	152
Avfall					
Behandlande	32	1 560	361	29	282
Förebyggande	19	246	71	7	198
Övrigt					
Behandlande	186	174	416	29	243
Förebyggande	23	235	102	40	124

RESULTAT OCH DISKUSSION

På en övergripande nivå finner vi inget stöd för Porterhypotesen. En tolkning är att det inte existerar något samband mellan företagens miljöinvesteringar och produktionens effektivitet. En annan möjlig förklaring är att företagens miljöskyddsinvesteringar är små jämfört med deras övriga kostnader. Miljöregleringarna är kanske därmed inte tillräckligt stringenta för att de ska påverka företagens effektivitet. En tredje orsak kan vara att den eventuella effekten av investeringarna är tidsfördröjd och att vårt datamaterial inte omfattar en tillräckligt lång tidsserie.

Det finns även andra problem relaterade till tolkningen av resultaten. Miljöskyddsinvesteringar kanske inte är ett bra mått på hur stringenta miljöregleringar är. Det finns åtminstone två anledningar till detta. För det första kan företag på egen hand välja att genomföra miljöinvesteringar. De kanske finner det företagsekonomiskt lönsamt att miljöprofilera sig på en marknad där konsumenterna blir alltmer miljömedvetna. Det krävs alltså inte nödvändigtvis någon form av politiskt beslutad reglering för att företag ska miljöskyddsinvestera, och därmed speglar inte heller miljöinvesteringarna politiskt beslutade regleringsnivåer. I detta fall överskattar vi miljöregleringstrycket. För det andra kan det vara svårt att separera miljöskyddsinvesteringar från andra investeringar. En anledning är att miljöskyddsinvesteringar inkluderar både rena miljöinvesteringar och den del i en investering som kan motiveras av miljöregleringar. Den här effekten kan ytterligare förstärkas eftersom det är upp till företagen att avgöra hur stor del miljöinvesteringen utgör. Ett exempel där det har varit svårt att klassificera investeringar är när de riktar sig mot vattenföroreningar. Några av industrierna använder så kallat processvatten som renas för att återanvändas i produktionen. Investeringar för att rena processvatten motiveras av vinsthänsyn och inte av miljöregleringar och ska därför inte betraktas som miljöskyddsinvesteringar. Sådana investeringar har, i vissa fall, klassificerats som miljöskyddsinvesteringar i SCB:s datamaterial, och är därför också ett skäl till att vi överskattar miljöregleringstrycket. Detta problem är förmodligen allvarligast för vattenintensiv produktion, det vill säga för industrierna massa och papper, kemi samt stål och metall.

Vi vill vi betona att det är en mycket komplex uppgift att på ett korrekt sätt testa Porterhypotesen, vilket kan vara en anledning till att föreliggande studie, tillsammans med en stor del av tidigare empiriska studier, inte finner något stöd för hypotesen. Svårigheterna är gemensamma och består bl a av: (1) att det är svårt att empiriskt mäta omfattningen/styrkan av miljöregleringarna som företagen möter på ett adekvat sätt; (2) att den miljöpolitik som faktiskt förs har svårt att uppfylla de kriterier som Porter nämner som förutsättningar för att politiken ska ha positiv effekt på företagens effektivitet. Exempelvis är miljöregleringar ofta administrativa till sin karaktär och går därmed emot Porters syn på hur miljöpolitik bör utformas.

Slutligen, att vi inte hittar något generellt stöd för Porterhypotesen ska inte ses som ett argument mot väl utformade miljöpolitiska styrmedel. Det primära syftet med att få företagen att investera i miljöskydd är inte att höja företagens produktivitet utan att minska deras miljöpåverkan.

1. Introduction

Swedish environmental policy often emphasizes the importance of "taking the lead". For example, Sweden has chosen a more ambitious climate policy target than required by the European Union (EU), namely a reduction of Swedish emissions of greenhouse gases by 40 percent by 2020 compared to the 1990 level. Government Bill 2008/09:162 emphasizes Sweden's role as a good example in making an effort to reduce climate change by showing that an offensive climate policy can indeed be combined with high economic growth.[6] This view of environmental policy is, however, the subject of constant debate.

A common argument is that environmental requirements induce private costs by forcing firms to make investments that crowd out other more productive investments, which hampers productivity growth and therefore competitiveness.[7] Professor Michael E. Porter of Harvard questioned this argument, and his view has become known as the Porter hypothesis (Porter, 1991). This hypothesis implies that levying stringent environmental regulations on firms enhances their productivity compared to competitors not subject to, or subject to lax, environmental regulations. A central message is that the connection between environmental regulation and competitiveness should be scrutinized within a dynamic framework (Porter and van der Linde, 1995).

The main objective of this paper is to test the Porter hypothesis by assessing static and dynamic effects of environmental policy on productivity within the Swedish manufacturing industry, specifically on the component total efficiency.[8] The paper adds mainly to previous literature by using unique data on environmental protection investments, divided into investments in *pollution control*[9] and *pollution prevention*, as a proxy for environmental regulation. The distinction between these types of investments is crucial to the understanding of the outcomes anticipated by the Porter hypothesis.

The international literature studying the Porter hypothesis is extensive. A comprehensive review reveals that neither theoretical nor empirical literature gives general support for the hypothesis (Brännlund and Lundgren, 2009). We argue that, to some extent, the Porter hypothesis has not yet been given a fair chance in the empirical literature, as dynamic effects are often neglected in empirical tests. Two exceptions are Managi et al. (2005) and Lanoie et al. (2008), who first estimate Total Factor Productivity (TFP) scores that then are used as dependent variables in regression analyses where explanatory lagged environmental stringency measures model dynamic effects. A disadvantage with these studies is, however, that environmental stringency is approximated by the cost of complying with environmental command- and-control regulations, such regulations are not emphasized by the Porter hypothesis.

---

[6] For example, Byung and Sickles (2004) studied 17 OECD countries from 1980 to 1990 and found that Sweden showed a relatively high productivity growth on average due to technological development and efficiency improvement. The reason for the productivity growth was that Sweden reduced CO_2 emissions at the same time as the GDP increased (p. 580). However, their study does not really say anything about whether the efforts of reducing CO_2 actually contributed to the GDP growth.

[7] For instance, the Confederation of Swedish Enterprise claims that such a policy will cause dramatic changes in industry structure, and fears that Swedish industry will suffer considerable costs and lose competitiveness (Resvik and Furbeck, 2005).

[8] To better comply with the Porter hypothesis, we decompose total efficiency into two components, technical and management efficiency (hence the "total"). This composition is discussed in Section 2.

[9] Porter and van der Linde (1995) use the term *pollution control* which is synonymous to *pollution treatment*.

The empirical test of the Porter hypothesis is performed as a two-step procedure, where total efficiency scores are first estimated by adopting a stochastic production frontier function approach. In the second step, the efficiency scores are used as the dependent variable in random effects regression analyses, where the independent variables are, e.g., investment in pollution control and pollution prevention. In order to assess whether these investments have dynamic effects on total efficiency these variables are also lagged. If positive effects are established we cannot reject the claim that environmental leadership will benefit the Swedish industry.[10] The estimations are based on firm level data from five Swedish industries for the period 1999-2004, and carried out for the pooled data as well as for the industries separately.

The paper is structured as follows. Section 2 describes the Porter hypothesis and how it relates to productive efficiency, and gives a discussion on previous literature. The theoretical framework for computing total efficiency is provided in Section 3, and Section 4 presents the empirical approach to estimating this efficiency. Then, a general model for the actual test of the Porter hypothesis is suggested. The data is described in Section 5, while the empirical results are presented in Chapter 6. Finally, Section 7 concludes the paper.

[10] Even if a positive relationship is found, improved total efficiency, resulting in increased competitiveness and profits, does not necessarily fully offset the initial costs of adapting to regulations.

2. The Porter hypothesis and previous analyses

2.1 The Porter hypothesis

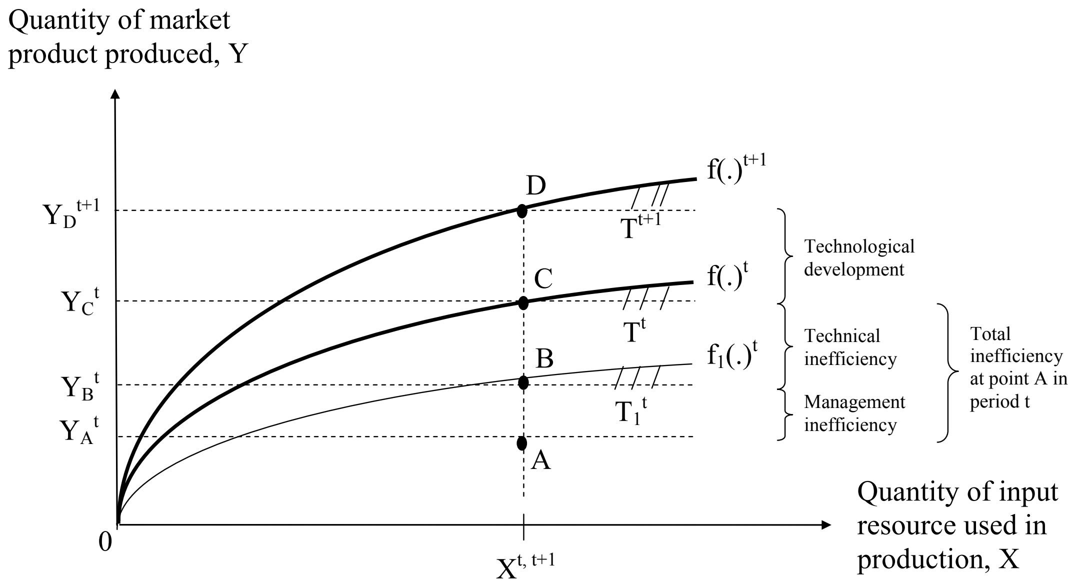
Porter and van der Linde (1995) claim that the commonly argued conflict between the economy and the environment derives from a static view of environmental policy measures and markets characterized by perfect information. Perfect information implies that the opportunities for profitable investments and innovations are discovered so that the firms always make optimal choices. These choices also include investments in pollution reduction. Hence, in a static world, with no market failures other than environmental externalities, environmental regulations will unavoidably lead to impaired productivity. Porter and van der Linde instead suggest a dynamic approach to viewing environmental regulation and competitiveness. They claim that the possibilities for dynamic competition are characterized by, e.g., technological possibilities, highly incomplete information, and organizational sluggishness (p. 99). Environmental policies based on market incentives, such as taxes, deposit-refund schemes, and tradable permits (p. 111), make firms aware of their non-optimal choices of technologies and use of production resources. Consequently, firms adapt continuously to the regulations, which then ultimately have positive dynamic effects on productivity and competitiveness. The resulting competitive improvement will generate revenues that eventually will offset, or even, exceed the initial costs of complying with the regulations. Hence, given that the revenues exceed the costs, the hypothesis is often regarded as a "win-win" hypothesis, as it suggest that firm profits increase via improved competitiveness at the same time as the environment improves.

The very heart of the Porter hypothesis is that firms operating under proper and stringent environmental regulation apply themselves continuously to innovative activities that improve resource productivity (Porter and van der Linde, 1995). Innovation can be interpreted in terms of environmental investments. Specifically, they argue that regulations should encourage investments in product and process changes (pollution prevention) to better utilize resources rather than investments in end-of-pipe or secondary treatment (pollution control), which is more costly (p. 111).

In the present paper, we start out from the literature on productive efficiency when interpreting and testing the Porter hypothesis.[11] This allows us to interpret changes in firm productivity resulting from changes in efficiency and/or from technological development. Based on Figure 1, we discuss our interpretation of how environmental policy according to the Porter hypothesis improves a firm's productivity and thus competitiveness.

[11] For a general introduction to this literature, see, e.g., Coelli et al. (2005), Kumbhakar and Lovell (2000), and Grosskopf (1993).

Figure 1. Environmental investments and effects on firm productivity



Assume a manufacturing sector during the periods t and $t+1$. The technology set of the sector, T^t, bounded by its frontier technology, $f(.)^t$, is defined by all possible combinations of output quantities (Y) and input quantities (X) in the initial period t. The frontier technology is assumed to correspond to the potentially most productive technology used in the sector during period t. Furthermore, assume that a firm within this sector, firm 1, has a production technology $f_1(.)^t$, which differs from the sector's most productive technology. The inefficient firm 1 is observed to operate at point *A*, producing Y_A^t by using input X^t. The distance between point A and B reflects management inefficiency and the distance between point B and C reflects technical inefficiency. Management inefficiency indicates that the firm could produce more output given X^t, by using its own production technology, $f_1(.)^t$, more efficiently. Technical inefficiency indicates that the firm could produce more output given X^t, by investing in the most productive technology used in the sector during period t, $f(.)^t$.

To address the Porter hypothesis, we assume that firm 1 initially operates under no, or lax, environmental regulation. However, as stringent regulations come into force, firms take measures to comply with these regulations. According to the Porter hypothesis, stringent environmental regulations stimulate firms to attend to organizational inertia and management problems, to invest in available technologies, and to develop the production process. Improving management and organization has positive effects on output, given technology, $f_1(.)^t$, and input use, i.e., management efficiency is improved (e.g., moving from point A to point B). Investing in a better production technology, $f(.)^t$, refers to the movement from point B to C, and is referred to as improved technical efficiency. Consequently, the environmental regulations have stimulated firm 1 to move its operation from the inefficient point A to, e.g., the efficient point C on the sectors technological frontier, $f(.)^t$. As a result, the firm's productivity is increased due to total efficiency having increased, in this case both due to improved management efficiency and technical efficiency. Accordingly, the firm is now more competitive as it, given a certain input quantity, e.g., X^t, has increased output by the total amount of $(Y_C^t - Y_A^t) > 0$.

Finally, developing the production process refers to technology development in general over time, and requires amongst others R&D. This is, in Figure 1, manifested by the shift of the sector's frontier technology from $f(.)^t$ to $f(.)^{t+1}$. Note that if firm 1 chooses to keep its technology, $f(.)^t$, in period $t+1$, and still operate at point C, it would again be interpreted as producing technically inefficiently (the distance between C and D). By again investing in a better technology, this time in $f(.)^{t+1}$, the firm could increase its production further to Y_D^{t+1}, and total efficiency is again achieved.

Total efficiency should be interpreted as a measure of how firm performance relates to a reference technology (a frontier) at a certain point in time, and not as a measure of the absolute relation between outputs and inputs. For instance, even if the firm is producing more output in period $t+1$ than in period t, given a certain input quantity, this does not necessarily imply that the firm has become more efficient in total, since the reference technology might have shifted.

Finally, dynamic effects are usually interpreted in terms of technological development. Yet, there may also be dynamic effects on total efficiency. If the firm responds to environmental regulations by making environmental protection investments, which in turn may have positive effects on total efficiency over time, the regulations indirectly generate dynamic effects on efficiency.

2.2 Previous analyses

The Porter hypothesis has attracted a great deal of attention, theoretically as well as empirically. A recent literature review concludes that whether or not a Porter effect is found in the theoretical analyses depends on the assumptions made (Brännlund and Lundgren, 2009). Generally, there must be another market imperfection present in addition to the environmental problem, which is indirectly corrected when producers adapt to environmental regulation. Crucial to the Porter hypothesis is then that such situations must be common, and that regulating authorities must know about them *ex ante*. However, conclusions that are based on theoretical models are hardly complete in the view of the Porter hypothesis. Incorporating all arguments of the hypothesis, and modeling the interplay between all relevant factors, is difficult in a neoclassical setting. Therefore, the question of whether there is any relevance of the Porter hypothesis is empirical in nature.

Most empirical research adopts approaches that, at best, can say something indirectly about a so-called 'weak' Porter effect, i.e., producer benefits that, at the least, partly offset the costs of adapting to environmental regulations. The majority of this research can be divided into analyses that study the effects on investment, innovation, and R&D and analyses that study the effects on efficiency and productivity.

Brännlund and Lundgren (2009) conclude that there is "*a lack of strong evidence for the existence of a strong Porter effect. However, it should also be noted that the literature does not provide 'strong' evidence against the hypothesis either*" (Brännlund and Lundgren, 2009, p. 100).[12]

We argue that the results from the literature should not be used to make a final general judgment about the hypothesis. The reason for this is that the empirical tests of the hypothesis have hardly ever considered dynamic effects, which are most crucial. As far as we know, Managi et al. (2005) and Lanoie et al. (2008) are the only two peer-reviewed studies to date that consider dynamics when studying the correlation between environmental regulation and productivity change. Also, taking dynamics into account is one of the most interesting and urgent future research directions, as pointed out by Brännlund and Lundgren (2009, p. 106).

Managi et al. (2005) study oil and gas production in the Gulf of Mexico at the field level. Using data covering a 28-year period from the late 1960s to the late 1990s, they first measure components of the Malmquist output-oriented TFP index by applying Data Envelopment Analysis (DEA). Then, to test the Porter hypothesis, they use the computed TFP scores as dependent variable in a polynomial distributed regression model where lagged measures of environmental stringency are included as independent variables. This allows for dynamic effects of stringency on productivity change. They find no significant relationship between environmental stringency and productivity change or technological change; stringency proxied by the cost of complying with environmental regulations. Whether this result should be interpreted as not supporting the Porter hypothesis is not obvious due to the command-and-control type of regulations imposed on the offshore oil and gas production (Managi et al., 2005, pp. 317). Porter and van der Linde (1995) do not recommend command-and-control: "*Environmental regulation should focus on outcomes, not technologies"* (p. 110).

Nevertheless, Managi et al. (2005) conclude that it is important to maintain a realistic view of environmental policy and its potential: "*An overly naïve conviction that there exists a near universal potential for win-win solutions in environmental problems could be used to justify poorly conceived environmental policies*" (p. 318).

Another study that brings dynamic effects of environmental regulation into focus is the one by Lanoie et al. (2008). It emphasizes the importance of extending the empirical research on the Porter hypothesis to (p. 122): (1) Are there dynamic effects? (2) Is the hypothesis more relevant for more polluting industries? (3) Is the hypothesis more relevant for industries that are more exposed to international competition?

Lanoie et al. (2008) perform an empirical analysis on pooled time-series and cross-section data for 17 Quebec manufacturing sectors 1985-1994. In a first step, they measure productivity change (TFP) using the Törnqvist index. In a second step they specify an expression that relates calculated TFP scores to environmental regulation variables and a set of control variables. The expression is estimated using a GLS procedure. Environmental regulation is measured as investment in pollution control equipment, and the authors state that it is likely to capture "command-and-control" measures. This means that environmental regulation is, most likely, proxied by investments in "end-of-pipe". Nevertheless, as Porter and van der Linde (1995) do not

[12] When "well-designed" environmental regulations result in complete cost neutralization it is referred to as "a strong Porter effect". If the "well-designed" regulation leads to a cost outcome that is lower than the second best regulatory alternative it is referred to as "a week Porter effect" (Brännlund and Lundgren, 2009, p. 82).

really argue for these types of measures, i.e., "*Regulations should encourage product and process changes to better utilize resources and avoid pollution early, rather than mandating end-of-pipe or secondary treatment, which is almost always more costly*" (p. 111), it is not obvious what to expect regarding effects on productivity. Also, as Lanoie et al. (2008) put it: "*[…], our proxy could be biased against the PH* (Porter Hypothesis)*"* (p. 123). However, their results show that static and dynamic effects of investment in pollution-control equipment on TFP are negative and positive, respectively. Additionally, the dynamic effects are stronger in industries that are more exposed to international competition.

Two recent analyses have tested the hypothesis on Swedish manufacturing data, although they did not test for dynamic effects. Brännlund (2008) uses a two-step model where TFP, measured by the Törnqvist index, is first calculated. Then TFP is used as dependent variable in a regression analysis, where a constructed regulatory intensity index is explanatory. There does not seem to be a relationship between environmental regulations and productivity growth. This could, according to the author either imply that regulations and productivity are unrelated or that the regulatory measure is not capturing regulation correctly. Brännlund and Lundgren (2009) use a factor demand model for the industry where a profit function, with a technology component dependent on the firm-specific tax on carbon dioxide, was specified (see also Brännlund and Lundgren, 2008). The results indicate that there is a reversed Porter effect in the energy-intensive industries. According to the authors, this could either imply that a tighter regulation that leads to environmental investments crowds out productive investments or that the model does not capture the true effects.

3. Efficiency – A stochastic frontier framework

Referring back to Figure 1 and the discussion on firm performance, we adopt a stochastic production frontier approach to estimate total efficiency scores.[13] Formally, let $y \in \Re_{+}$ and $x = (x_1,...,x_N) \in \Re_{+}^{N}$ be the produced output and a vector of inputs used, respectively. Then, for observation i, the stochastic production frontier function may be expressed in logarithmic form as (see, e.g., Kumbhakar and Lovell, 2000, p. 72):[14]

$$\ell n y^i = f\left(\ell n x^i ; \alpha\right) + v^i - u^i , \qquad u^i \geq 0 , \qquad (1)$$

where α is a vector of production technology parameters to be estimated, and $\varepsilon^i = v^i - u^i$ is the error term that is composed of a two-sided noise component, v^i, and a non-negative total inefficiency component, u^i. In this case, inefficiency is referred to as being output-oriented; i.e., it measures to what extent output can maximally be increased for a given input vector. Specifically, production is efficient on the technological frontier when $u^i = 0$ and inefficient beneath the frontier when $u^i > 0$.

The noise component is assumed to be $v^i \sim iid\, N(0,\sigma_v^2)$ and distributed independently of the inefficiency component, which in turn is assumed to be $u^i \sim iid\, N^{+}(0,\sigma_u^2)$. In other words, the distribution of the inefficiency component of the error term is assumed to be non-negative and half normal. Finally, v^i and u^i are distributed independently of regressors, x^i (Kumbhakar and Lovell 2000, p. 74).

As u^i in equation (1) is an inefficiency component, a recalculation is made to obtain an expression of total efficiency for each observation *i* (Kumbhakar and Lovell, 2000, p. 78):

$$TE^i = \exp\left[-u^i\right], \qquad 0 < TE^i \leq 1 \qquad (2)$$

Then, production is efficient in total if $TE^i = 1$ and inefficient if $0 < TE^i < 1$. In the latter case, the interpretation is that if $TE^i = \gamma^i$, $0 < \gamma^i < 1$, production could be increased by $(1/\gamma - 1) \cdot 100$ percent, to achieve maximum output from given inputs. The TE^i variable in equation (2) constitutes the dependent variable in the empirical regression model used to test the Porter hypothesis.

---

[13] We decompose total efficiency into two components, technical and management efficiency, the latter allows firms to organize and run businesses inefficiently (see Figure 1 in Section 2).

[14] Regarding stochastic frontier analysis, and the discussion in this section, see also, e.g., Coelli et al. (2005) and Greene (2008a, 2008b).

4. The estimated model

The empirical approach used to test the Porter hypothesis is a two-step procedure, where the first step involves estimation of total efficiency scores according to equations (1) and (2).[15] In the second step, the estimated efficiency scores, $\hat{TE}^{i}$, are regressed on a set of explanatory variables, e.g., environmental protection investment variables.[16] The variances of the parameter estimates of the investment variables are then the basis for the hypothesis tests.

4.1 The first step – The stochastic production frontier model

First, stochastic production frontier estimations are conducted to generate total efficiency scores. In this case, the production function is parameterized using a flexible translog specification, which, for producer k and time period t, in the case of one output (y) and two inputs, i.e., capital (x_1) and labor (x_2), is estimated as:

$$\begin{aligned} \ell n y^{kt} &= \alpha_0 + \alpha_1 \ell n x_1^{kt} + \alpha_2 \ell n x_2^{kt} \\ &+ \frac{1}{2}\alpha_{11}\left[\ell n x_1^{kt}\right]^2 + \alpha_{12}\ell n x_1^{kt}\ell n x_2^{kt} \\ &+ \frac{1}{2}\alpha_{22}\left[\ell n x_2^{kt}\right]^2 + v^{kt} - u^{kt} \end{aligned} \quad . \tag{3}$$

This expression satisfies symmetry, i.e., $\alpha_{12} = \alpha_{21}$, and is estimated by using the stochastic frontier regression option in LIMDEP (Version 9.0 Reference Guide). Then, in line with equation (2), total efficiency scores, $0 < \hat{TE}^{kt} \leq 1$, are obtained.

4.2 The second step – The Porter hypothesis test

In the second step, the estimated efficiency scores, $\hat{TE}^{i}$, are used as the dependent variable in a regression model, which includes several explanatory variables in order to test different hypotheses regarding the variability in $\hat{TE}^{i}$. A general guideline is that variables that are exogenously given to the producer belong to the second step (Lovell, 1993, p. 53). In this analysis, it is assumed that firms' environmental protection investments are enforced by exogenously given environmental regulations.

A general model for testing the Porter hypothesis is formulated as follows:

---

[15] As Lovell (1993, p. 53) puts it: "*[…] the scores make attractive dependent variables in a second-stage regression analysis. Results of this second-stage analysis can help guide public policy […]*".

[16] First we tried to estimate the two steps simultaneously as a Battese and Coelli panel model, available in Limdep Version 9.0. However, the estimations did not converge, possible due to insufficient variation in data.

$$\hat{TE}^{kt} = \phi + \omega I_{PP}^{kt,t-j} + \psi I_{PC}^{kt,t-j} + \lambda W^{kt} + \eta^{kt}, \; j = 1,...,J \text{ lagged years} \qquad (4)$$

where $I_{PP}^{kt,t-j}$ is a vector of contemporaneous (t) and lagged ($t-j$) variables regarding firm *k*'s investment in pollution prevention in period *t*, and $I_{PC}^{kt,t-j}$ is a vector of contemporaneous and lagged variables regarding investments in pollution control. Accordingly, the contemporaneous variables allow us to test whether there are any static effects of the investments on total efficiency, and the lagged variables whether there are any dynamic effects. Furthermore, W^{kt} is a vector of other variables that might affect efficiency (described in Section 5). In particular, it should be noted that we control for technological development through year dummies. This is important for our purpose as efficiency is measured as the distance to a reference technology frontier that may shift over the years. The last term on the right-hand side, η^{kt}, is an error term that is assumed uncorrelated with all other right-hand side variables, in time, and across firms. Estimations are carried out using a random effects regression approach, and *t*-tests on the estimated parameters of pollution prevention, $\hat{\omega}$, and pollution control, $\hat{\psi}$, are then performed in order to evaluate the validity of the Porter hypothesis.

Which signs of the estimators in equation (4) can we expect? Regarding investments in pollution prevention, $\hat{\omega}$, from an economic theoretical perspective we expect a negative sign in the short run, i.e., a negative contemporaneous effect on total efficiency. Also, Porter and van der Linde (1995, p. 98, pp. 107) do not rule out short-run costs for firms to comply with environmental regulation. A significant positive (or even non-significant) sign would, however, not contradict the Porter hypothesis. Yet, the testing of the hypothesis should focus mainly on the lagged effects of investments in pollution prevention. In the long run, the hypothesis suggests a significant positive sign, i.e., a positive dynamic effect on efficiency. The hypothesis test is H_0: $\omega^{t-j} > 0$ and H_A: $\omega^{t-j} \leq 0$. Thus if $\omega^{t-j} > 0$ we do not reject the Porter hypothesis and if $\omega^{t-i} \leq 0$ we reject the Porter hypothesis.

Regarding investments in pollution control, $\hat{\psi}$, from an economic theoretical perspective we expect a negative sign in the short run. The Porter hypothesis is less clear when it comes to this type of investment. It argues that methods such as imposing a specific technology by command-and-control should be seen as a last resort (Porter van der Linde, 1995, p. 110, Footnote 13), and that commanding end-of-pipe solutions are, in most cases, more costly than pursuing pollution prevention policies (p. 111). In that case, investments in pollution control contribute less to efficiency than do investments in pollution prevention. This would imply smaller positive dynamic effects on total efficiency

5. Data

5.1 Descriptives

The data has been created by matching two different official surveys collected annually by Statistics Sweden: (1) industrial economic statistics; and (2) the industries' environmental protection expenditures. Both surveys are collected on the firm level. The data covers the period 1999-2004. We have restricted the analysis to the following industries: Wood and wood products (NACE 20), Pulp and paper (NACE 21), Chemicals (NACE 24), Rubber and plastics (NACE 25), and Basic metals (NACE 27).

First, to obtain firm level total efficiency scores, stochastic production functions are estimated based on inputs and a single output. The output, y, is measured as value added, and each firm uses capital, x_1, and labor, x_2, as inputs.[17] Capital is the net capital stock of machines and inventories measuring assets after write-offs[18], and labor is total employment, measured in number of employees. Then, to test the Porter hypothesis, the efficiency scores are regressed on environmental protection investments variables and relevant control variables, in accordance with the model in equation (4). Environmental protection investments, deflated from current to fixed prices by CPI, are measured as share of total variable cost in order to control for the fact that large firms might have relatively large environmental protection investments.

The control variables are, besides year dummies that control for time specific effects such as technological development and sector dummies, *business cycle* and *gross investments* (normalized with total variable cost). As a proxy for *business cycle* the capacity utilization rate is used.[19] Since efficiency is likely to vary with business cycles, e.g., decrease in booms due to adjustment costs in expansion of production, a negative sign is expected. Gross investments are included as all kind of investments are expected to influence efficiency negatively in an initial phase. For instance, it usually takes time to install machinery and to get it to run properly, a negative sign is thus expected. Table 1 provides descriptive statistics, on variables related to the first and second step of the analysis, in terms of averages over the years 1999-2004.

The Chemicals, Pulp and paper, and Basic metals industries are much larger than the Wood and wood products and Rubber and plastic industries. The Chemicals industry produces the highest valued added, roughly SEK 884 million, and Pulp and paper is the most capital intensive. Furthermore, compared to variable cost, gross investment is highest in the Chemicals and the Pulp and paper industries, nearly 11 percent and 10 percent, respectively. The others come close to 5-6 percent. Finally, Pulp and paper also distinguishes itself from others with respect to environmental protection investments which, as a share of total variable cost, are 2.3-5.2 times higher. Overall, envi-

[17] Implicit deflation factors have been derived from national account series of sector-specific value added in current and fixed prices. The national accounts use different deflation factors when transforming current prices to fixed prices (i.e., the production values are deflated with producer price index and the input values are deflated by the factor price index).

[18] Since the write-offs reflect the annual loss of economic value in fixed assets, we have not deflated the net capital stock explicitly.

[19] The capacity utilization rate is an average for the sector. Insufficient demand is the main reason for not utilizing full capacity (Swedish National Institute of Economic Research, 2010).

ronmental protection investments are small in relation to total variable production costs.

Table 1. Descriptive statistics

Variables	Wood and wood products NACE 20	Pulp and paper NACE 21	Chemicals NACE 24	Rubber and plastic NACE 25	Basic metals NACE 27
Value added, y_1	114,789	671,429	884,114	93,580	513,738
1000 SEK	(149,721)	(982,294)	(3,363,910)	(94,844)	(1,001,350)
Capital, x_1	82,131	910,005	438,561	50,994	450,298
1000 SEK	(141,236)	(1,452,500)	(1,078,540)	(58,923)	(933,279)
Labor, x_2	235	580	582	183	739
Number of employees	(287)	(618)	(1,447)	(174)	(1,323)
Business cycle	0.86	0.94	0.84	0.77	0.87
Percent	(0.03)	(0.01)	(0.04)	(0.01)	(0.02)
Gross investment	23,176	146,179	178,612	13,201	100,073
1000 SEK	(49,876)	(298,743)	(626,233)	(17,535)	(228,397)
Total variable cost	474,595	1,535,070	1,634,430	261,329	1,597,160
1000 SEK	(577,713)	(1,886,790)	(4,417,810)	(272,251)	(2,712,160)
Env. inv. as percent	0.14	0.73	0.31	0.20	0.31
of total variable cost	(0.50)	(1.61)	(0.63)	(0.65)	(0.95)
Number of obs.	279	304	289	223	199

5.2 Environmental protection investments

Data on environmental protection investments is collected through annual surveys to firms with at least 20 employees.[20] Samples of roughly 1,000 firms are drawn from a population of 4,500 firms, and firms with at least 250 employees are surveyed each year. The overall response rate was around 60 percent in 1999 and 2000; then it increased to 88-91 percent in the period 2001-2004 (Statistics Sweden, 2001; 2002; 2003; 2004; 2005).[21]

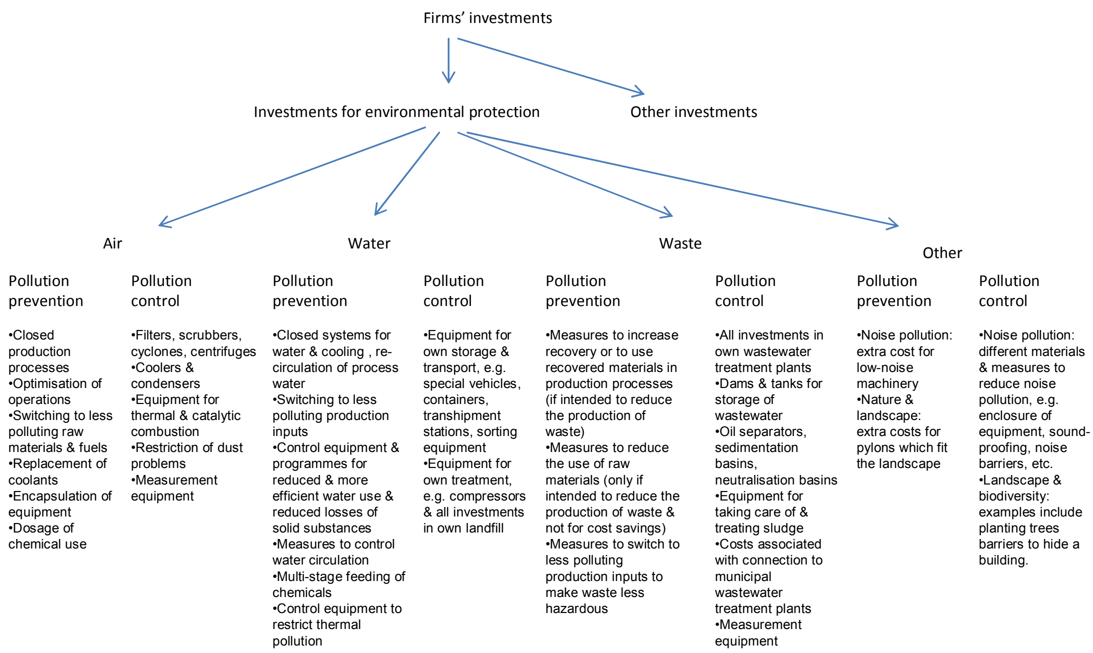
According to the internationally agreed definition, environmental protection investments include *"…all capital expenditure related to environmental protection activities (involving methods, technologies, processes, equipment or parts thereof), where the main purpose is to collect, treat, monitor and control, reduce, prevent or eliminate pollutants and pollution or any other degradation of the environment, resulting from the operating activity of the company"* (Eurostat, 2001). Environmental protection investments are divided into pollution prevention and pollution control. Investments in pollution prevention comprise "*capital expenditures for new or adaptation of existing methods, technologies, processes, equipment designed to prevent or reduce the amount of pollution created at the source*" (Eurostat, 2001). Investments in pollution control are "*capital expenditures for methods, technologies, processes or equipment designed to collect and remove pollution and pollutants after their creation, prevent the spread of and measure the level of the pollution, and treat and dispose of pollutants*" (Eurostat, 2001). Environmental protection investments are further divided into environmental domains (air, water, waste, and

[20] See Olsson and Eberhardson (2003) for an evaluation of the environmental protection expenditures from a data quality and collection perspective, and for an English version of the questionnaire.

[21] The response rate is typically lower for firms with fewer than 250 employees. The high response rate from 2001 and onwards reduces the risk for sample selection problems, and is due to the fact that the survey became better known among the responding firms, and that some of the questions became compulsory.

other). Hence, the survey data set is unique in terms of detailed and comprehensive investment data on the firm level. A big drawback is, however, that investments aiming at reducing carbon dioxide emissions are not systematically covered in the survey. Figure 2 gives an overview of the categorization, including specific examples of investments.

Figure 2. Description of firms' investments



Source: Eurostat (2001) and own work.

Table 2 shows the environmental protection investments, divided into pollution prevention and pollution control, per sector and environmental domain.[22] The Wood and Rubber and plastics industries have smaller mean investments and the Pulp and paper industry has higher mean investments, irrespective of environmental domain.[23] The mean investments in pollution control are generally higher than the mean investments in pollution prevention.[24] Broadly speaking, the patterns of environmental protection investments between industries can be explained by different (mean) firm sizes in the respective industries and that the industries can differ when it comes to which environmental problems they need to solve and which technologies are best suited for

[22] About 40 percent of the environmental protection investments, in monetary terms, are made to control or prevent air pollution. Table A1 in Appendix exemplifies these investments for the industries in the analysis.

[23] With the exception of other investments in pollution control, which are higher for the Wood, Chemicals and Basic metals industries than for the Pulp and paper industry.

[24] With the exception of water investments in the Wood industry, air investments and other investments in the Pulp and paper industry, and other investments in the Rubber and plastic industry where mean investments in pollution prevention are higher.

dealing with these problems. Moreover, we cannot rule out that the industries to some extent face different regulation.

Table 2. Environmental protection investments (1000 SEK)

Variables	Wood and wood products NACE 20	Pulp and paper NACE 21	Chemicals NACE 24	Rubber and plastic NACE 25	Basic metals NACE 27
Mean Air control	126	1,061	866	142	969
(St.d.)	(665)	(4,231)	(3,377)	(685)	(2,704)
# of positive values	42	72	94	34	73
Mean Air prevention	92	2,872	650	50	620
(St.d.)	(563)	(10,302)	(2,411)	(224)	(2,389)
# of positive values	37	77	85	34	56
Mean Water control	25	5,838	809	46	560
(St.d.)	(183)	(21,848)	(2,855)	(390)	(2,092)
# of positive values	24	119	86	19	57
Mean Water prevention	29	2,978	133	15	152
(St.d.)	(202)	(12,805)	(616)	(113)	(601)
# of positive values	14	90	64	9	46
Mean Waste control	32	1,560	361	29	282
(St.d.)	(173)	(15,717)	(2,915)	(186)	(1,055)
# of positive values	44	82	52	26	52
Mean Waste prevention	19	246	71	7	198
(St.d.)	(138)	(1,680)	(380)	(94)	(1,615)
# of positive values	29	55	32	12	29
Mean Other control	186	174	416	29	243
(St.d.)	(598)	(601)	(3,177)	(127)	(749)
# of positive values	74	65	61	28	54
Mean Other prevention	23	235	102	40	124
(St.d.)	(131)	(1,865)	(533)	(364)	(697)
# of positive values	36	46	41	15	40
Total number of obs.	279	304	289	223	199

Porter and Van der Linde (1995) specifically mention market-based policy instruments and that regulation should be neutral with respect to what technology each firm can choose in order to reduce their environmental burden. Regulation of air emissions in Sweden is, to a significant degree, in line with what Porter and Van der Linde (1995) consider a dynamically efficient regulation, i.e., a regulation that can create productivity gains that offset the costs of regulation. The nitrogen oxides (NO_x) charge and the sulfur tax are two important market-based policy instruments that are used to reduce pollutants.[25] All analyzed industries face the sulfur tax, which is levied on oil with a sulfur content exceeding 0.1 percent by weight. The NO_x charge is imposed on plants with furnaces with useful energy production[26] exceeding 25 GWh per year, which in the analyzed sample are most common in the Wood and wood products, Pulp and paper, and Chemical sectors. However, there are also elements that are not in line with dynamically efficient regulation. Pollution prevention investments related to the exchange of cooling material in cooling systems are relatively common, and are regulated by command-and-control.[27] In 2002, investments related to cooling material equaled

[25] Since 1991, Sweden has had a CO_2 tax that is also considered dynamically efficient.

[26] Useful energy can be steam, hot water, or electricity produced in a boiler and used in production processes or heating of factory buildings. After deducting administrative costs (1 % of the revenues), the revenues are refunded to the same sources that paid the charge, but in proportion to output of useful energy.

[27] During the period studied, the use of cooling material was regulated by the Swedish EPA's promulgation on cooling material (SNFS 1992:16), which qualifies as a command-and-control type of regulation.

15 percent of total pollution prevention investment expenditures related to air; yet in 2003-2004, they had decreased to 1-2 percent.

6. Results

As described in the previous sections, we adopt a two-step procedure to test the hypothesis that environmental regulations improve firms' total efficiency. First, to estimate efficiency scores, we adopt a stochastic production frontier approach.[28] Second, we test whether the estimated efficiency scores are significantly correlated with investments in pollution control and pollution prevention using a linear random effects regression method. The results presented in this section are based on three different models. The models differ in how static and dynamic effects of environmental regulation, through environmental protection investments, on total efficiency are captured. In Model 1, environmental protection investments are included as an average of the last three years, i.e., the investment variable for year *t* is defined as [*inv(t)* + *inv(t-1)* + *inv (t-2)*]/*3*. Thus, in this case, the investment variable does not distinguish between static and dynamic effects and we cannot properly test the Porter hypothesis. In Model 2, environmental protection investments are instead divided into two variables that separately capture static and accumulated dynamic effects of regulations, i.e., *inv(t)* and *[inv(t-1)* + *inv(t-2)]/2*, respectively. Finally, Model 3 further divides the dynamic effects into separate years: *inv(t)* captures the static effect and *inv(t-1)* and *inv (t-2)* capture the dynamic effects of environmental regulation.

6.1 Analysis on manufacturing - Aggregated environmental protection investments

Table 3 provides the results from estimating Models 1 to 3 on a pooled data sample for the included industries. Industry-specific effects on total efficiency are captured by dummies.

The results give no support for the Porter hypothesis. None of the models show any significant correlation between environmental protection investments and total efficiency. However, investments in pollution prevention have the signs expected from the Porter hypothesis. The estimates of the control variables *business cycle* and *gross investments* show the expected signs. The estimates of the time dummies indicate technological development over time.

---

[28] Table A2 and A3 in Appendix provide the parameters of the estimated production functions and the efficiency scores, for all sectors pooled together and for each sector separately, respectively.

Table 3. Test of the Porter hypothesis on manufacturing; linear random effects[29]

Independent variables	Estimate (t-value) Model 1	Model 2	Model 3
Intercept	**1.16 (10.88)	**1.16 (10.87)	**1.15 (10.84)
Year 2002	**0.02 (2.39)	**0.02 (2.33)	**0.02 (2.37)
Year 2003	**0.02 (2.67)	**0.02 (2.63)	**0.02 (2.60)
Year 2004	**0.05 (6.58)	**0.05 (6.63)	**0.05 (6.66)
Business cycle	**-0.41 (-3.23)	**-0.41 (-3.22)	**-0.41 (-3.21)
Gross investments to net capital stock ratio	**-0.38 (-6.38)	**-0.37 (-6.03)	**-0.36 (-5.97)
Pollution control period t	0.21 (0.28)	0.33 (0.84)	0.30 (0.74)
Pollution control period t-1		-0.04 (-0.07)	-0.09 (-0.24)
Pollution control period t-2			-0.04 (-0.07)
Pollution prevention period t	0.19 (0.22)	-0.56 (-1.27)	-0.52 (-1.16)
Pollution prevention period t-1		0.64 (0.92)	0.04 (0.08)
Pollution prevention period t-2			0.64 (1.31)
Number of observations	524	524	524
Lagrange multiplier test for rem/fem over OLS	**120.22	**121.60	**122.53
R^2	0.24	0.24	0.24

••: Significant at the 5 percent level; •: Significant at the 10 percent level

6.2 Analysis on manufacturing - Environmental protection investments separated into environmental domains

Support for the Porter hypothesis should first and foremost be expected in environmental domains that are subject to incentive-based policy measures, which in Sweden mainly involves air. To further see whether we can find any statistically significant support for the Porter hypothesis, the environmental protection investments are divided into the domains air, water, waste, and other; see Models 1 and 2 in Table 4.[30]

Model 1 shows that none of the average environmental protection investment variables are significant, with the exception of investment in waste pollution prevention. As model 2 shows, the accumulated dynamic effect of investments in air pollution control is statistically significant. For waste, there is a statistically confirmed positive correlation between investments in pollution prevention and efficiency, implying that we cannot reject the Porter hypothesis in this case. We can however conclude that the results give no general support for the Porter hypothesis. Finally, the estimates of the control variables *business cycle* and *gross investments* show the expected signs.

[29] To save space, the estimates of the sector specific effects on total efficiency are omitted.

[30] Model 3 was excluded due to the lack of degrees of freedom.

Table 4. Test of the Porter hypothesis on manufacturing – separating investments into environmental domains; linear random effects models[31]

Independent variables	Estimate (t-value) Model 1	Estimate (t-value) Model 2
Intercept	**1.15 (10.74)	**1.15 (10.57)
Year 2002	**0.02 (2.39)	**0.02 (2.24)
Year 2003	**0.02 (2.75)	**0.02 (2.64)
Year 2004	**0.05 (6.61)	**0.05 (6.54)
Business cycle	**-0.40 (-3.16)	**-0.40 (-3.07)
Gross investments to total variable cost ratio	**-0.37 (-6.23)	**-0.37 -(6.03)
Pollution control Air period t	-1.33 (-0.88)	-0.02 (-0.03)
Pollution control Air average period t-1and t-2		*-2.55 (-1.68)
Pollution prevention Air period t	1.19 (0.68)	-0.27 -(0.31)
Pollution prevention Air average period t-1and t-2		1.12 (0.77)
Pollution control Water period t	0.39 (0.31)	0.36 (0.50)
Pollution control Water average period t-1and t-2		0.30 (0.30)
Pollution prevention Water period t	-1.41 (-1.18)	-0.76 (-1.32)
Pollution prevention Water average period t-1and t-2		-0.65 (-0.67)
Pollution control Waste period t	3.31 (1.41)	0.59 (0.59)
Pollution control Waste average period t-1and t-2		2.28 (1.03)
Pollution prevention Waste period t	*6.35 (1.94)	2.23 (0.57)
Pollution prevention Waste average period t-1and t-2		*4.29 (1.85)
Pollution control Other period t	-0.72 (-0.19)	3.31 (1.42)
Pollution control Other average period t-1and t-2		-2.04 (-0.70)
Pollution prevention Other period t	6.05 (1.20)	0.76 (0.10)
Pollution prevention Other average period t-1and t-2		4.60 (1.34)
Number of observations	524	524
Lagrange multiplier test for rem/fem over ols	**113.04	**108.32
R^2	0.25	0.26

**: Significant at the 5 percent level; *: Significant at the 10 percent level

---

31 To save space, the estimates of the sector specific effects on efficiency are omitted.

6.3 Sector-specific analysis – Environmental protection investments separated into environmental domains

To bring yet another dimension into the study, we test the Porter hypothesis in each sector separately. As argued in Lanoie et al. (2008, p. 121), the Porter hypothesis is more relevant for sectors that are comparatively more exposed to international competition, such as Pulp and Paper, Chemical and Basic Metals.[32] Table 5 presents the results of Model 2.[33] As with the pooled data in sections 6.1 and 6.2, environmental protection investment generally does not have any significant effect on total efficiency. However, by analyzing each sector separately, a few exceptions are found in the industries that are more exposed to international competition. Investments in other pollution control have a negative direct effect on efficiency in the Pulp and paper industry. Investments in air and water pollution prevention have a negative direct effect on efficiency in the Basic metals industry. Yet, the hypothesis test should focus mainly on the lagged effects of investments in pollution prevention, i.e. dynamic effects. The only result where we cannot reject the Porter hypothesis concerns investments in waste pollution prevention, as they have a positive dynamic effect on efficiency in the chemical industry. That the results differ between industries is natural since their environmental influence and the regulations they face also differ; see Section 5.2. The estimate of the control variable *gross investments* shows the expected sign.

To sum up, we find no general significant effect of environmental protection investments on total technical efficiency. The most comparable study, i.e., Lanoie et al. (2008), found that investments in pollution control affect TFP negatively first and positively with a lag. This effect is not supported by our result.

---

[32] They measure exposedness to international competition as exports + imports/total shipments.

[33] Since *business cycle* is measured at the sector level, it is excluded from the analysis. Also, the Rubber and plastics industry is excluded due to lack of variation in environmental protection investment variables.

Table 5. Test of the Porter hypothesis on the industry level; linear random effects model

Independent variables	Estimate (t-value)			
	Model 2			
	Wood and wood prod. (NACE 20)	Pulp and paper (NACE 21)	Chemical (NACE 24)	Basic metals (NACE 27)
Intercept	**0.83 (22.48)	**0.75 (25.23)	**0.71 (19.95)	**0.83 (53.15)
Year 2002	*-0.05 (-1.73)	**0.07 (3.82)	0.004 (0.23)	-0.00 (-0.00)
Year 2003	-0.01 (-0.25)	**0.05 (3.00)	**0.06 (2.99)	**0.02 (2.00)
Year 2004	-0.01 (-0.49)	**0.09 (5.11)	**0.09 (4.13)	**0.02 (2.14)
Gross investments to net capital stock ratio	**-0.94 (-2.75)	**-0.49 (-2.97)	-0.22 -(1.57)	**-0.68 (-4.32)
Pollution control Air period t	-0.02 (-0.00)	-2.49 (-1.40)	-1.57 (-0.71)	0.79 (0.28)
Pollution control Air average period t-1and t-2	11.10 (0.47)	-4.61 (-1.23)	-8.95 (-1.59)	5.80 (1.08)
Pollution prevention Air period t	21.24 (0.75)	-4.61 (-1.23)	1.18 (0.42)	*-2.78 (-1.94)
Pollution prevention Air average period t-1and t-2	35.24 (0.73)	0.45 (0.16)	3.05 (0.66)	1.28 (0.45)
Pollution control Water period t	145.44 (0.65)	0.35 (0.30)	-0.62 (-0.22)	0.89 (0.19)
Pollution control Water average period t-1and t-2	-79.04 (-0.79)	-0.38 (-0.26)	-11.78 (-1.07)	-7.77 (-0.86)
Pollution prevention Water period t	--	-1.22 (-1.37)	11.46 (0.47)	*-17.92 (-1.79)
Pollution prevention Water average period t-1and t-2	--	-0.52 (-0.37)	16.10 (0.66)	16.10 (1.44)
Pollution control Waste period t	-56.65 (-1.28)	0.61 (0.35)	2.53 (0.65)	-1.35 (-0.25)
Pollution control Waste average period t-1and t-2	-27.66 (-1.04)	1.86 (0.51)	-0.20 (-0.02)	-4.58 (-0.44)
Pollution prevention Waste period t	11.20 (1.05)	-0.44 (-0.04)	5.78 (0.67)	--
Pollution prevention Waste average period t-1and t-2	-20.71 (-0.59)	-18.98 (-0.74)	**84.63 (1.97)	--
Pollution control Other period t	26.05 (0.82)	*-60.73 (-1.80)	10.24 (1.54)	3.77 (0.52)
Pollution control Other average period t-1and t-2	6.49 (0.53)	-23.37 (-1.35)	-3.04 (-0.60)	3.61 (0.42)
Pollution prevention Other period t	-81.97 (-0.45)	-9.27 (-0.68)	2.16 (0.10)	32.74 (1.37)
Pollution prevention Other average period t-1and t-2	13.61 (0.39)	8.05 (0.25)	4.29 (0.41)	-2.21 (-0.07)
Number of observations	107	150	121	84
Lagrange multiplier test for rem/fem over ols	**22.46	**21.25	**35.39	0.00
R^2	0.27	0.32	0.33	0.46

**: Significant at the 5 percent level; *: Significant at the 10 percent level

6.4 Discussion

In general, we find no support for the Porter hypothesis. One explanation is that there simply is no Porter effect and no relation between environmental protection investments and firm efficiency. Another possible explanation is that the relative size of the firms' environmental protection investments to total variable cost (and total investments) is very small. This could reflect rather lax environmental regulations. However, even if regulation has an effect on efficiency the relative small size of environmental investments makes it difficult to statistically isolate the effect. A third reason as to why we find no effect on firm efficiency could be that the effect occurs with a longer time lag than we are able to study.

There are other problems related to the interpretation of the test results. Environmental investment might not be the best proxy for environmental regulation stringency, and there are at least two causes as to why stringency might be overstated: 1) Firms might voluntary choose to invest in the environment since it could be profitable to have an environmental image on a market where consumers are becoming increasingly aware of the environment. In this case there is not necessarily a need for environmental regulation in order for firms to invest. In that case, environmental investments do not necessarily reflect regulation stringency; 2) There might be some inconsistencies in the survey material due to difficulties in separating environmental investments from other investments. The reason for this is that environmental investments include both pure environmental investments and the share of regular investments that is motivated by environmental regulations. This effect might be reinforced as it is up to the firms to decide how much of a regular investment that is environmental. One example is that it seems to have been difficult to separate water investments in pollution control from regular investments. Some of the industries, e.g., Pulp and paper, Chemicals, and Basic metals, have closed-loop systems where waste water is purified to be reused in the production process (i.e., polluted water is not emitted). Investments in closed-loop systems are motivated by profitability and not by environmental regulation, and should therefore be considered as regular investments. The data indicate that such investments have been included as environmental protection investments and, again, environmental investment will therefore not correctly reflect regulation stringency

7. Concluding remarks

Swedish environmental policy emphasizes the importance of "taking the lead". The argument to lead relates to the so-called Porter hypothesis, which suggests that a country that pursues a relatively strict environmental policy can improve its competitiveness and therefore obtain higher growth. Using data on environmental protection investments for the Swedish industry, this paper provides a new approach to test the Porter hypothesis. Based on a two-stage approach, firms' total efficiency in production is first estimated using a stochastic production frontier function approach. Then the formerly estimated efficiency scores are used as the dependent variable in linear random effects regression analyses, where investments in environmental protection are included as independent variables. We extend previous analyses by using a unique data set that enables us to separate environmental protection investments into pollution prevention and pollution control, and into different environmental domains (air, water, waste, or other).

The Porter hypothesis suggests that investments in pollution prevention are better than investments in pollution control, since investments in prevention have positive dynamic effects on firm performance. Our data thus allow for a more proper test of the hypothesis than in previous literature. In general, we find no support for the Porter hypothesis. There could be several reasons for this: 1) There is simply no Porter effect and no relation between environmental protection investments and firm efficiency; 2) the size of the firms' environmental protection investments is small relative to total variable costs (and to total investments), which could be due to rather lax environmental regulation. However, even if regulation has an effect on firm efficiency, it might be statistically difficult to isolate the effect of regulation from the effects of other much larger non-environmental investments; 3) the potential effect of environmental protection investment occurs with a longer time lag than we have been able to study.

A source of misinterpretation of the Porter hypothesis tests run here is that environmental protection investment might not be a good proxy for environmental regulation stringency. For instance, the data set analysed indicate that some non-environmental investments are included as environmental protection investments. Due to a couple of additional data related problems we conclude that what seemed like the perfect measure also has flaws, and that this analysis therefore cannot be used to make a final general judgement of the hypothesis, i.e., of whether or not environmental leadership pays off.

The fact that we do not find any general support for the Porter hypothesis should not be interpreted as an argument against well-designed environmental policies. The primary motivation for stimulating firms to protect the environment is not to increase firm efficiency, but to decrease environmental damage originating from market failures. If environmental protection investments crowd out more productive measures within the company, we cannot expect firms to voluntarily invest sufficiently in environmental protection. Hence, in order to reach the established environmental goals, policies that stimulate investments may be motivated. While preventive measures that stimulate technological innovations may be important, since they focus on measures taken "at the source", they are not necessarily preferred when there are ambitions to reach a particular goal by a given point in time. In that case, policies that adopt treatment measures of "end of pipe" character can be preferable.

References

Brännlund, R. (2008) Productivity and Environmental Regulations, Umeå Economic Studies, No. 728.

Brännlund, R. and T. Lundgren (2008) Environmental Policy and Profitability – Evidence from Swedish Industry, Umeå Economic Studies, No 750.

Brännlund, R. and T. Lundgren (2009) Environmental Policy without Costs? A Review of the Porter Hypothesis, *International Review of Environmental and Resource Economics*, **3**(2), 75-117.

Byung, M. J. and R. C. Sickles (2004) The Role of Environmental Factors in Growth Accounting, *Journal of Applied Econometrics*, **19**(5), 567-591.

Coelli, T. J., D. S. P. Rao, C. J. O'Donnell and G. E. Battese (2005) *An Introduction to Efficiency and Productivity Analysis*, Springer Science + Business Media, LLC, New York.

Eurostat (2001). *Definitions and guidelines for measurement and reporting of company environmental protection expenditure*, Eurostat Task Force, "Environmental Protection Expenditure – Industry Data Collection, Doc. ENV/01/3.6A", European Commission.

Government Bill 2008/09:162, En sammanhållen klimat- och energipolitik (in Swedish).

Grosskopf, S. (1993) Efficiency and Productivity, in Fried, H. O., C. A. K. Lovell and S. S. Schmidt (eds.) *The Measurement of Productive Efficiency – Techniques and Applications*, Oxford University Press, New York.

Greene, W.H. (2008a) *Econometric Analysis*, Pearson Education, Inc., Upper Saddle River, New Jersey.

Greene, W.H. (2008b) The Econometric Approach to Efficiency Analysis, in Fried, H.O., C.A.K. Lovell and S.S. Schmidt (eds.), *The Measurement of Productive Efficiency and Productivity Growth*, Oxford University Press, Inc., New York.

Kumbhakar, S.C and C.A.K. Lovell (2000) *Stochastic Frontier Analysis*, Cambridge University Press.

Lanoie, P., M. Patry and R. Lajeunesse (2008) Environmental Regulation and Productivity: Testing the Porter Hypothesis, *Journal of Productivity Analysis*, **30**(2), 121-128.

LIMDEP Version 9.0 Reference Guide by William H Greene, Econometric Software, Inc. NY USA 1986-2007.

Lovell, C.A.K. (1993) Production Frontiers and Productive Efficiency, in Fried, H. O., C. A. K. Lovell and S. S. Schmidt (eds.) *The Measurement of Productive Efficiency – Techniques and Applications*, Oxford University Press, New York.

Managi, S., J.J. Opaluch, D. Jin, and T.A. Grigalunas (2005) Environmental Regulations and Technological Change in the Offshore Oil and Gas Industry, *Land Economics*, **81**(2), 303-319.

Olsson, N. and M. Eberhardson (2003) "Environmental protection expenditure in Swedish industry - Evaluation of new variables, data quality and estimation methods", Statistics Sweden and Eurostat.

Porter, M.E. (1991) America's Green Strategy, *Scientific American*, **264**: 168.

Porter, M.E. and C. van der Linde (1995) Toward a New Conception of the Environment-Competitiveness Relationship, *Journal of Economic Perspectives*, **9**(4), 97-118.

Resvik, B. and A. Furbeck (2005) Varför ska vi låta klimatmålet sänka vår industri i onödan? *Dagens Industri*, 2005-12-20 (in Swedish).

SNFS 1992:16 Statens naturvårdsverks kungörelse med föreskrifter om kyl- och värmepumpanläggningar innehållande CFC, övriga CFC, haloner, HCFC och HFC ("köldmediekungörelsen"), beslutade den 3 september 1992 (in Swedish).

Statistics Sweden (2009) Personal communication Nov, 2009.

Statistics Sweden (2005) "Miljöskyddskostnader i industrin 2004" (Environmental Protection Expenditure in Industry 2004), MI 23 SM 0501, Statistics Sweden.

Statistics Sweden (2004) ”Miljöskyddskostnader i industrin 2003” (Environmental Protection Expenditure in Industry 2003), MI 23 SM 0401, Statistics Sweden.
Statistics Sweden (2003) ”Miljöskyddskostnader i industrin 2002” (Environmental Protection Expenditure in Industry 2002), MI 23 SM 0301, Statistics Sweden.
Statistics Sweden (2002) ”Miljöskyddskostnader i industrin 2001” (Environmental Protection Expenditure in Industry 2001), MI 23 SM 0201, Statistics Sweden.
Statistics Sweden (2001) ”Miljöskyddskostnader i industrin 1999 och 2000” (Environmental Protection Expenditure in Industry 1999 and 2000), MI 23 SM 0101, Statistics Sweden.
Swedish National Institute of Economic Research (2010) Personal communication with Roger Knudsen.

Appendix

Table A1. Investments in pollution prevention and control for the category air

Industry	Pollution prevention	Pollution control
Wood & wood products NACE 20	Connection to district heating; Furnace rebuilt for better burning; Flue gas operation control of furnace central; Exchange of cooling material in cooling system	Scrubber; Cyclone against dust; Dust filter for slicing plant
Pulp & paper NACE 21	Installation of low NOx burner for oil-heated furnace; Catalyst exchange/purifier; Rebuilding of bark furnace to improve efficiency level and to reduce NOx emissions; Exchange of cooling material in cooling system	Modifying electricity filters; Addition of ventilators; Flue gas purifying with bicarbonate as added ingredient; Supervision equipment for NOx meter
Chemicals NACE 24	Fuel Switching (e.g., cleaner fuel oil); Exchange of cooling material in cooling system	Ventilation system; Improved air filtration; Installation of NOx meter; Thermal combustion of processing air VOC
Rubber & plastics NACE 25	Heat exchanger for condenser of gas containing VOC; Exchange of cooling material in cooling system	Air purification equipment (e.g., enable replacement of VOC); Purification filter for heat exchanger
Basic metals NACE 27	Catalytic NOx purifier; Exchange of material in refrigerator; Ventilation, exchange of freon to water	Dust filters for purification of extractor; Purchase of meter

Source: Statistics Sweden (2009) and own work.

Table A2. Parameters of the estimated production function, and the mean efficiency scores; pooled data sample for the included industries (t-values within parentheses)

Variable	Estimate (t-value)
Constant	**0.73 (3.01)
a1	**0.43 (5.72)
a2	**0.29 (2.12)
a11	**0.11 (7.93)
a12	**-0.12 (-4.98)
a22	**0.18 (4.25)
Lambda	**1.23 (16.29)
Sigma	**0.48 (1583.89)
Mean TE	
All sectors together	0.75
Wood and wood prod. (NACE 20)	0.73
Pulp and paper (NACE 21)	0.75
Chemicals (NACE 24)	0.79
Rubber and plastic (NACE 25)	0.74
Basic metals (NACE 27)	0.75
Log Likelihood	-559.22
Bayesian Information Criterion	0.91

Note: The parameters of the estimated production functions:
a1 = ln(x1)
a2 = ln(x2)
a11 = 0.5*((log(x1))*(ln(x1)))
a12 = ((ln(x11))*(ln(x2)))
a22 = 0.5*((ln(x2))*(ln(x2)))

Table A3. The parameters of the estimated production functions, and the mean efficiency scores; the industries- analyzed separately (t-values within parentheses).

Variable	Wood and wood prod. (NACE 20)	Pulp and paper (NACE 21)	Chemical (NACE 24)	Basic metals (NACE 27)
Constant	0.09 (0.21)	0.60 (0.81)	**2.11 (4.23)	-1.12 (1.57)
a1	**0.54 (5.80)	**0.60 (2.91)	**0.89 (5.03)	-0.28 (1.02)
a2	**0.51 (2.43)	0.25 (0.58)	*-0.57 (1.90)	**1.53 (3.50)
a11	**0.08 (3.53)	**0.18 (4.66)	**0.14 (3.94)	0.01 (0.22)
a12	**-0.12 (-4.23)	**-0.20 (-2.95)	**-0.24 (-4.14)	0.07 (0.86)
a22	**0.13 (2.31)	*0.24 (1.86)	**0.47 (4.75)	**-0.18 (-1.33)
Lambda	**2.95 (7.06)	**2.17 (8.53)	**1.67 (7.98)	**0.85 (4.82)
Sigma	**0.47 (318.61)	**0.52 (403.89)	**0.54 (351.66)	**0.34 (241.63)
Mean TE	0.73	0.71	0.71	0.84
Log Likelihood	-57.27	-110.46	-135.44	-41.17
Bayesian Information Criterion	0.51	0.88	1.09	0.63

Titles in the Working Paper Series

No	Author	Title	Year
1	Warne, Anders and Anders Vredin	Current Account and Business Cycles: Stylized Facts for Sweden	1989
2	Östblom, Göran	Change in Technical Structure of the Swedish Economy	1989
3	Söderling, Paul	Mamtax. A Dynamic CGE Model for Tax Reform Simulations	1989
4	Kanis, Alfred and Aleksander Markowski	The Supply Side of the Econometric Model of the NIER	1990
5	Berg, Lennart	The Financial Sector in the SNEPQ Model	1991
6	Ågren, Anders and Bo Jonsson	Consumer Attitudes, Buying Intentions and Consumption Expenditures. An Analysis of the Swedish Household Survey Data	1991
7	Berg, Lennart and Reinhold Bergström	A Quarterly Consumption Function for Sweden 1979-1989	1991
8	Öller, Lars-Erik	Good Business Cycle Forecasts- A Must for Stabilization Policies	1992
9	Jonsson, Bo and Anders Ågren	Forecasting Car Expenditures Using Household Survey Data	1992
10	Löfgren, Karl-Gustaf, Bo Ranneby and Sara Sjöstedt	Forecasting the Business Cycle Not Using Minimum Autocorrelation Factors	1992
11	Gerlach, Stefan	Current Quarter Forecasts of Swedish GNP Using Monthly Variables	1992
12	Bergström, Reinhold	The Relationship Between Manufacturing Production and Different Business Survey Series in Sweden	1992
13	Edlund, Per-Olov and Sune Karlsson	Forecasting the Swedish Unemployment Rate: VAR vs. Transfer Function Modelling	1992
14	Rahiala, Markku and Timo Teräsvirta	Business Survey Data in Forecasting the Output of Swedish and Finnish Metal and Engineering Industries: A Kalman Filter Approach	1992
15	Christofferson, Anders, Roland Roberts and Ulla Eriksson	The Relationship Between Manufacturing and Various BTS Series in Sweden Illuminated by Frequency and Complex Demodulate Methods	1992
16	Jonsson, Bo	Sample Based Proportions as Values on an Independent Variable in a Regression Model	1992
17	Öller, Lars-Erik	Eliciting Turning Point Warnings from Business Surveys	1992
18	Forster, Margaret M	Volatility, Trading Mechanisms and International Cross-Listing	1992
19	Jonsson, Bo	Prediction with a Linear Regression Model and Errors in a Regressor	1992
20	Gorton, Gary and Richard Rosen	Corporate Control, Portfolio Choice, and the Decline of Banking	1993
21	Gustafsson, Claes-Håkan and Åke Holmén	The Index of Industrial Production – A Formal Description of the Process Behind it	1993

22	Karlsson, Tohmas	A General Equilibrium Analysis of the Swedish Tax Reforms 1989-1991	1993
23	Jonsson, Bo	Forecasting Car Expenditures Using Household Survey Data- A Comparison of Different Predictors	1993
24	Gennotte, Gerard and Hayne Leland	Low Margins, Derivative Securitites and Volatility	1993
25	Boot, Arnoud W.A. and Stuart I. Greenbaum	Discretion in the Regulation of U.S. Banking	1993
26	Spiegel, Matthew and Deane J. Seppi	Does Round-the-Clock Trading Result in Pareto Improvements?	1993
27	Seppi, Deane J.	How Important are Block Trades in the Price Discovery Process?	1993
28	Glosten, Lawrence R.	Equilibrium in an Electronic Open Limit Order Book	1993
29	Boot, Arnoud W.A., Stuart I Greenbaum and Anjan V. Thakor	Reputation and Discretion in Financial Contracting	1993
30a	Bergström, Reinhold	The Full Tricotomous Scale Compared with Net Balances in Qualitative Business Survey Data – Experiences from the Swedish Business Tendency Surveys	1993
30b	Bergström, Reinhold	Quantitative Production Series Compared with Qualiative Business Survey Series for Five Sectors of the Swedish Manufacturing Industry	1993
31	Lin, Chien-Fu Jeff and Timo Teräsvirta	Testing the Constancy of Regression Parameters Against Continous Change	1993
32	Markowski, Aleksander and Parameswar Nandakumar	A Long-Run Equilibrium Model for Sweden. The Theory Behind the Long-Run Solution to the Econometric Model KOSMOS	1993
33	Markowski, Aleksander and Tony Persson	Capital Rental Cost and the Adjustment for the Effects of the Investment Fund System in the Econometric Model Kosmos	1993
34	Kanis, Alfred and Bharat Barot	On Determinants of Private Consumption in Sweden	1993
35	Kääntä, Pekka and Christer Tallbom	Using Business Survey Data for Forecasting Swedish Quantitative Business Cycle Varable. A Kalman Filter Approach	1993
36	Ohlsson, Henry and Anders Vredin	Political Cycles and Cyclical Policies. A New Test Approach Using Fiscal Forecasts	1993
37	Markowski, Aleksander and Lars Ernsäter	The Supply Side in the Econometric Model KOSMOS	1994
38	Gustafsson, Claes-Håkan	On the Consistency of Data on Production, Deliveries, and Inventories in the Swedish Manufacturing Industry	1994
39	Rahiala, Markku and Tapani Kovalainen	Modelling Wages Subject to Both Contracted Increments and Drift by Means of a Simultaneous-Equations Model with Non-Standard Error Structure	1994
40	Öller, Lars-Erik and Christer Tallbom	Hybrid Indicators for the Swedish Economy Based on Noisy Statistical Data and the Business Tendency Survey	1994

41	Östblom, Göran	A Converging Triangularization Algorithm and the Intertemporal Similarity of Production Structures	1994
42a	Markowski, Aleksander	Labour Supply, Hours Worked and Unemployment in the Econometric Model KOSMOS	1994
42b	Markowski, Aleksander	Wage Rate Determination in the Econometric Model KOSMOS	1994
43	Ahlroth, Sofia, Anders Björklund and Anders Forslund	The Output of the Swedish Education Sector	1994
44a	Markowski, Aleksander	Private Consumption Expenditure in the Econometric Model KOSMOS	1994
44b	Markowski, Aleksander	The Input-Output Core: Determination of Inventory Investment and Other Business Output in the Econometric Model KOSMOS	1994
45	Bergström, Reinhold	The Accuracy of the Swedish National Budget Forecasts 1955-92	1995
46	Sjöö, Boo	Dynamic Adjustment and Long-Run Economic Stability	1995
47a	Markowski, Aleksander	Determination of the Effective Exchange Rate in the Econometric Model KOSMOS	1995
47b	Markowski, Aleksander	Interest Rate Determination in the Econometric Model KOSMOS	1995
48	Barot, Bharat	Estimating the Effects of Wealth, Interest Rates and Unemployment on Private Consumption in Sweden	1995
49	Lundvik, Petter	Generational Accounting in a Small Open Economy	1996
50	Eriksson, Kimmo, Johan Karlander and Lars-Erik Öller	Hierarchical Assignments: Stability and Fairness	1996
51	Url, Thomas	Internationalists, Regionalists, or Eurocentrists	1996
52	Ruist, Erik	Temporal Aggregation of an Econometric Equation	1996
53	Markowski, Aleksander	The Financial Block in the Econometric Model KOSMOS	1996
54	Östblom, Göran	Emissions to the Air and the Allocation of GDP: Medium Term Projections for Sweden. In Conflict with the Goals of SO_2, SO_2 and NOX Emissions for Year 2000	1996
55	Koskinen, Lasse, Aleksander Markowski, Parameswar Nandakumar and Lars-Erik Öller	Three Seminar Papers on Output Gap	1997
56	Oke, Timothy and Lars-Erik Öller	Testing for Short Memory in a VARMA Process	1997
57	Johansson, Anders and Karl-Markus Modén	Investment Plan Revisions and Share Price Volatility	1997
58	Lyhagen, Johan	The Effect of Precautionary Saving on Consumption in Sweden	1998
59	Koskinen, Lasse and Lars-Erik Öller	A Hidden Markov Model as a Dynamic Bayesian Classifier, with an Application to Forecasting Busi-	1998

		ness-Cycle Turning Points	
60	Kragh, Börje and Aleksander Markowski	Kofi – a Macromodel of the Swedish Financial Markets	1998
61	Gajda, Jan B. and Aleksander Markowski	Model Evaluation Using Stochastic Simulations: The Case of the Econometric Model KOSMOS	1998
62	Johansson, Kerstin	Exports in the Econometric Model KOSMOS	1998
63	Johansson, Kerstin	Permanent Shocks and Spillovers: A Sectoral Approach Using a Structural VAR	1998
64	Öller, Lars-Erik and Bharat Barot	Comparing the Accuracy of European GDP Forecasts	1999
65	Huhtala , Anni and Eva Samakovlis	Does International Harmonization of Environmental Policy Instruments Make Economic Sense? The Case of Paper Recycling in Europe	1999
66	Nilsson, Charlotte	A Unilateral Versus a Multilateral Carbon Dioxide Tax - A Numerical Analysis With The European Model GEM-E3	1999
67	Braconier, Henrik and Steinar Holden	The Public Budget Balance – Fiscal Indicators and Cyclical Sensitivity in the Nordic Countries	1999
68	Nilsson, Kristian	Alternative Measures of the Swedish Real Exchange Rate	1999
69	Östblom, Göran	An Environmental Medium Term Economic Model – EMEC	1999
70	Johnsson, Helena and Peter Kaplan	An Econometric Study of Private Consumption Expenditure in Sweden	1999
71	Arai, Mahmood and Fredrik Heyman	Permanent and Temporary Labour: Job and Worker Flows in Sweden 1989-1998	2000
72	Öller, Lars-Erik and Bharat Barot	The Accuracy of European Growth and Inflation Forecasts	2000
73	Ahlroth, Sofia	Correcting Net Domestic Product for Sulphur Dioxide and Nitrogen Oxide Emissions: Implementation of a Theoretical Model in Practice	2000
74	Andersson, Michael K. And Mikael P. Gredenhoff	Improving Fractional Integration Tests with Bootstrap Distribution	2000
75	Nilsson, Charlotte and Anni Huhtala	Is CO_2 Trading Always Beneficial? A CGE-Model Analysis on Secondary Environmental Benefits	2000
76	Skånberg, Kristian	Constructing a Partially Environmentally Adjusted Net Domestic Product for Sweden 1993 and 1997	2001
77	Huhtala, Anni, Annie Toppinen and Mattias Boman,	An Environmental Accountant's Dilemma: Are Stumpage Prices Reliable Indicators of Resource Scarcity?	2001
78	Nilsson, Kristian	Do Fundamentals Explain the Behavior of the Real Effective Exchange Rate?	2002
79	Bharat, Barot	Growth and Business Cycles for the Swedish Economy	2002
80	Bharat, Barot	House Prices and Housing Investment in Sweden and the United Kingdom. Econometric Analysis for the Period 1970-1998	2002
81	Hjelm, Göran	Simultaneous Determination of NAIRU, Output Gaps and Structural Budget Balances: Swedish Evi-	2003

		dence	
82	Huhtala, Anni and Eva Samalkovis	Green Accounting, Air Pollution and Health	2003
83	Lindström, Tomas	The Role of High-Tech Capital Formation for Swedish Productivity Growth	2003
84	Hansson, Jesper, Per Jansson and Mårten Löf	Business survey data: do they help in forecasting the macro economy?	2003
85	Boman, Mattias, Anni Huhtala, Charlotte Nilsson, Sofia Ahlroth, Göran Bostedt, Leif Mattson and Peichen Gong	Applying the Contingent Valuation Method in Resource Accounting: A Bold Proposal	
86	Gren, Ing-Marie	Monetary Green Accounting and Ecosystem Services	2003
87	Samakovlis, Eva, Anni Huhtala, Tom Bellander and Magnus Svartengren	Air Quality and Morbidity: Concentration-response Relationships for Sweden	2004
88	Alsterlind, Jan, Alek Markowski and Kristian Nilsson	Modelling the Foreign Sector in a Macroeconometric Model of Sweden	2004
89	Lindén, Johan	The Labor Market in KIMOD	2004
90	Braconier, Henrik and Tomas Forsfält	A New Method for Constructing a Cyclically Adjusted Budget Balance: the Case of Sweden	2004
91	Hansen, Sten and Tomas Lindström	Is Rising Returns to Scale a Figment of Poor Data?	2004
92	Hjelm, Göran	When Are Fiscal Contractions Successful? Lessons for Countries Within and Outside the EMU	2004
93	Östblom, Göran and Samakovlis, Eva	Costs of Climate Policy when Pollution Affects Health and Labour Productivity. A General Equilibrium Analysis Applied to Sweden	2004
94	Forslund Johanna, Eva Samakovlis and Maria Vredin Johansson	Matters Risk? The Allocation of Government Subsidies for Remediation of Contaminated Sites under the Local Investment Programme	2006
95	Erlandsson Mattias and Alek Markowski	The Effective Exchange Rate Index KIX - Theory and Practice	2006
96	Östblom Göran and Charlotte Berg	The EMEC model: Version 2.0	2006
97	Hammar, Henrik, Tommy Lundgren and Magnus Sjöström	The significance of transport costs in the Swedish forest industry	2006
98	Barot, Bharat	Empirical Studies in Consumption, House Prices and the Accuracy of European Growth and Inflation Forecasts	2006
99	Hjelm, Göran	Kan arbetsmarknadens parter minska jämviktsarbetslösheten? Teori och modellsimuleringar	2006
100	Bergvall, Anders, Tomas Forsfält, Göran	KIMOD 1.0 Documentation of NIER´s Dynamic Macroeconomic General Equilibrium Model of the	2007

	Hjelm, Jonny Nilsson and Juhana Vartiainen	Swedish Economy	
101	Östblom, Göran	Nitrogen and Sulphur Outcomes of a Carbon Emissions Target Excluding Traded Allowances - An Input-Output Analysis of the Swedish Case	2007
102	Hammar, Henrik and Åsa Löfgren	Explaining adoption of end of pipe solutions and clean technologies – Determinants of firms' investments for reducing emissions to air in four sextors in Sweden	2007
103	Östblom, Göran and Henrik Hammar	Outcomes of a Swedish Kilometre Tax. An Analysis of Economic Effects and Effects on NOx Emissions	2007
104	Forsfält, Tomas, Johnny Nilsson and Juhana Vartianinen	Modellansatser i Konjunkturinstitutets medelfristprognoser	208
105	Samakovlis, Eva	How are Green National Accounts Produced in Practice?	2008
107	Forslund, Johanna, Per Johansson, Eva Samakovlis and Maria Vredin Johansson	Can we by time? Evaluation. Evaluation of the government's directed grant to remediation in Sweden	2009
108	Forslund, Johanna Eva Samakovlis, Maria Vredin Johansson and Lars Barregård	Does Remediation Save Lives? On the Cost of Cleaning Up Arsenic-Contaminated Sites in Sweden	2009
109	Sjöström, Magnus and Göran Östblom	Future Waste Scenarios for Sweden on the Basis of a CGE-model	2009
110	Österholm, Pär	The Effect on the Swedish Real Economy of the Financial Crisis	2009
111	Forsfält, Tomas	KIMOD 2.0 Documentation of changes in the model from January 2007 to January 2009	2009
112	Österholm, Pär	Improving Unemployment Rate Forecasts Using Survey Data	2009
113	Österholm, Pär	Unemployment and Labour-Force Participation in Sweden	2009
114	Jonsson, Thomas and Pär Österholm	The Properties of Survey-Based Inflation Expectations in Sweden	2009
115	Hjelm, Göran and Kristian Jönsson	In Search of a Method for Measuring the Output Gap of the Swedish Economy	2010
116	Vartiainen, Juhana	Interpreting Wage Bargaining Norms	2010
117	Mossfeldt, Marcus and Pär Österholm	The Persistent Labour-Market Effects of the Financial Crisis	2010
118	Östblom, Göran, Maria Ljunggren Söderman and Magnus Sjöström	Analysing future solid waste generation – Soft linking a model of waste management with a CGE-model for Sweden	2010