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Assessing Vulnerability of Selected Sectors Under Environmental Tax Reform:

The Issue of Pricing Power

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Abstract: This paper investigates pricing power, an important criterion for identifying sectors that would be vulnerable under environmental tax reform. Environmental tax reform, defined here as introduction of carbon taxes alongside reductions in labour taxes, could bear heavily on sectors that are energy intensive and highly traded, in particular if their options for adapting technology are limited. However, a sector with pricing power has less to fear as, rather than having to conform to the world price, it can set its price to accommodate a tax mark-up.

To assess pricing power, a model of long-run price setting is specified and tested. Significant and plausible results emerged from this exercise, indicating that pricing power as a major aspect of a sector's relative vulnerability can be assessed. Of the six sectors analysed, the Basic metals sector had least pricing power and the Non-metallic minerals sector had most. As proxies for the world price, the German price tended to matter more than the US price. Thus, competitiveness fears are reduced not just where there is good potential for adapting technology but also if application of environmental tax reform is EU-wide.

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1. Introduction

This paper describes an analysis of price-setting behaviour by six energy intensive sectors in six EU countries. The purpose of the analysis is to investigate the relative strengths of world prices and domestic costs in determining the sectors' output prices, with a view to assessing pricing constraints facing the sectors.

The aim underlying this study is to throw light on how a sector would fare under the introduction of carbon or energy taxes. Such taxes raise domestic costs and the question is to what extent can the sector pass these on by virtue of its being a price-setter; alternatively is the sector a price-taker meaning that, if it failed to absorb the cost increase, it would be vulnerable to competitive disadvantage under such tax reforms?

The study forms part of a larger project, called COMETR (Competitiveness Effects of Environmental Tax Reform, a Specific Targeted Research Project supported by the EU's Sixth Framework Programme for Research and coordinated by the National Environmental Research Institute in Denmark). To date measures of vulnerability and threats to competitiveness have availed of a number of features such as energy share, trade exposure, share of the market, market power, and to some extent on potential for technological efficiency. Other investigations in this field include Fagerberg (1988), Shroeter *et al.,* (1988), Durand *et al.* (1992), Turner and Van't Dack (1993), Fagerberg (1996), Barker and Köhler (1998), Wolfram (1999), Williams *et al.* (2002), European Commission (2004), ZhongXiang (2004). The purpose of this study is to extend our understanding of vulnerability by looking at the recent pricing behaviour to see how constrained is a sector's pricing.

Concern is expressed that carbon taxes would harm traded energy intensive sectors by causing their prices to rise out of line with those of competitors in foreign and domestic markets. It is feared that these sectors might cease production or relocate to jurisdictions with lower environmental taxes, or laxer regulations - dubbed pollution havens. Relocation could therefore result in carbon emissions moving elsewhere with little or no environmental improvement in global terms, merely carbon leakage. A sector with pricing power however is not constrained when costs rise and there is less reason to fear that they would cease or relocate.

In the next section, after briefly describing the context for this study, six potentially vulnerable sectors are selected for analysis of their pricing power. The paper proceeds to summarise the literature on price setting and formulates a model of price setting behaviour. The data used and the results of applying the model are then described. After a discussion of results by sector, some implications are outlined, followed by a concluding section.

2. Context

The context is the series of environmental tax reforms that were implemented in a number of EU countries, mostly during the period of the nineties. These tax reforms were the subject of the COMETR project, an *ex post* study of their effects on competitiveness. The reforms in question were the carbon or energy taxes introduced alongside revenue recycling, mainly in the form of reduced labour taxes. Six EU countries introduced such environmental tax reforms (ETRs) as follows:

(Table 1)

Other modules of the COMETR study have investigated the effects of ETR on greenhouse gas emissions, GDP and prices, and on uptake of new technology (COMETR, 2007).

Given the focus on competitiveness, the sectors deemed potentially most vulnerable and selected for study were those that, in addition to being characterised by high energy intensity, were subject to trade exposure as measured by export and import intensity. Sectors were ranked according to, among other things, energy expenditure as a share of gross value added, the share of exports in the total value of output, and imports as a share of home demand (output plus imports minus exports). Knowledge

of specific country characteristics was brought to bear on the selection in order to obtain a balanced representation of sectors, taking into account such issues as the prominence of wood and wood products in the Swedish and Finnish economies. The seven selected sectors were as follows:
(Table 2)

An idea of the vulnerability of these sectors under the introduction of an energy or carbon tax can be gauged by their unit energy costs. Expenditure on energy inputs expressed as a percentage of sectoral gross value added at basic prices is shown in Table 3.

It is seen that, in addition to considerable variation in energy unit costs between sectors as expected, there is considerable variation between countries within sectors at this level of detail. Turning to trade exposure, this is described in Tables 4 and 5 for exports and imports respectively. For reasons that will become clear, it is the share of trade with EU countries shown here that is of special interest.
(Table 4)
(Table 5)

As shown, the majority of imports were sourced from the EU, and a majority of exports were destined for the EU. At the lower end of trade shares with the EU was the sector Non-metallic mineral products (of which cement forms a large share), though, like Food beverages and tobacco, this sector tended to trade a relatively low share of its output in any event.

3. Literature Review and Price-Setting Model

Where firms operate in a perfectly competitive market they are price takers on that market and the price equals the marginal cost of production. However, in many cases firms may operate under imperfect competition having a degree of market power. In this latter case firms may be expected to set their prices as a mark-up on cost, with the mark-up on cost reflecting the shape of the demand curve that they face. Where firms have market power and are able to discriminate between markets, producers will maximise profits by charging different prices in each market. This is the basis of a measure that is frequently used, the Lerner Index, where the difference between price and marginal cost (as a proportion of price) measures the relative monopoly price distortion, as illustrated for example in Schroeter (1988) and Wolfram (1999).

Price setting behaviour by firms has been the subject of intensive research in the literature over the past 30 years. Calmfors and Herin (1978) showed that while some Swedish firms exposed to international competition were price takers others were less dependent on world market prices. Pricing to market is a well-established phenomenon (Krugman, 1987) and there is evidence of its importance in explaining price changes in small open economies (Naug and Nymoen, 1996). Callan and Fitz Gerald (1989) show how Irish firms' pricing decisions changed over the 1980s with the advent of the EMS and the growing importance of the EU market; increasingly Irish firms' pricing decisions were determined by German producer prices (and the bilateral exchange rate). Friberg and Vredin (1996) show how pricing behaviour by Swedish firms evolved over time with a reduction in the proportion pricing in Swedish crowns and an increase in the proportion invoicing in foreign currencies.

Thus it is an empirical question, tested in this paper, whether firms in a particular sector in a particular country are price takers or whether they have market power, setting their own prices in a manner such that they can pass on at least some of any changes in domestic costs.

In this study the market price-setting power of the selected sectors is assessed for the ETR countries, namely, Denmark, Germany, Finland, the Netherlands, Sweden and the UK. With data being available for Ireland it is included for interest. The aim is to understand the global market context and establish by reference to past behaviour which sectors can 'pass on' cost increases, such as environmental taxes, or whether they maintain sectoral output prices at a competing foreign price level.

Two polar cases of the pricing of domestic manufacturing output can be posited, where prices are either:

- externally determined, and the sector is a price-taker, or
- determined as a mark-up on domestic costs, and the sector is a price-setter.

In the latter case the sector is less exposed to competitive pressures and can be said to have market power. It is less vulnerable in the event of the introduction of the tax element of ETR, such as a carbon or energy tax, which it can pass on. If on the other hand the former case holds and prices for the sector's product are externally determined, then that sector could indeed be vulnerable in the event of the introduction of a carbon tax, in the absence of adequate mitigating measures such as revenue recycling or if there are no worthwhile technological adaptations that it can undertake. A mixture of the two cases is also a possibility.

In specifying a price-setting model one may start with a perfectly competitive market, where the law of one price holds. Using p_i to denote the domestic price of sector i's product, and p^f to denote the foreign price expressed in domestic currency, then in the perfectly competitive situation:

$$p_i = p^f_i$$

Meanwhile in an oligopolistic situation profit-maximising firms set prices as an optimal mark-up over marginal costs:

$$p_i = mc_i + \mu_i$$

where mc_i is the marginal cost and μ_i is the mark-up, which can be zero. Leaving aside reactions to short-term events, these relationships should reflect the two sets of influences on the setting of output price. The following model could therefore be estimated:

$$p_i = \alpha_0 + \alpha_1 mc_i + \alpha_2 p^f_i$$

One could thereby test for evidence that prices are either set domestically i.e. according to domestic costs, or otherwise set by the foreign price. Three outcomes are of interest: the coefficient α_1 on domestic costs is significant, α_2 is significant so that the external price matters), or a mixture of the two.

The equation above is taken to be a long-run price relationship. It is consistent with perfectly competitive markets that require goods to be perfect substitutes. It is plausible that for some sectors there is room for market power to hold but there is a limit on price divergence in the long run. This is because at sufficiently high domestic prices all markets are contestable such that entry can occur. Obstfeld and Rogoff (2000) show that declining transport costs can have a big impact on relative demand for domestic and foreign goods (thus explaining the falling 'home trade bias puzzle') and hence on relative prices – this could justify a time trend but it is not used in the following analysis.

If estimated coefficients on foreign prices are significant, the sector is likely to be a price taker and therefore subject to competition. If the estimated coefficients on only domestic costs are significant the sector is likely to be immune from competition from abroad. Some mixture of the two is possible.

Purchasing power parity (PPP) is imposed for the long-run structural relationship between exchange rates and foreign prices.

The basic model to be estimated then becomes:

$$P_d^* = f(P^f_j, R_j, W_k)$$

where P_d^* = the long-run wholesale price for the sector's domestic output in domestic currency terms

P^f_j = the world wholesale price index in the 'competing' country or bloc *j*

R_j = the exchange rate with country or bloc j

W_k = the price index for domestic input factor *k*. Wage rates are used.

The US being a dominant trading bloc, its price is taken as the 'world price' or the price in competing country j. In a second run the German price is used as the world or competing country price. To allow for different lengths of responses to changes in prices and exchange rates, a lagged response is allowed for, by inclusion of an error-correction type term. The error correction representation is:

$$\Delta Y_t = \alpha_1 + \lambda(Y_{t-1} - \beta_1 X_{t-1}) + \sum \alpha_2(i)\Delta y_{t-i} + \sum \alpha_3(i)\Delta X_{t-i} + \varepsilon_{yt} \qquad (1)$$

where β = parameters of the cointegrating vector, lambda λ is the speed of adjustment parameter where a higher value indicates a faster convergence from short-run dynamics to the long-run situation, and ε_{yt} = white-noise disturbance with no moving average part, and α_i are all parameters.

Equations are estimated for each sector for each country investigated.

4. Data

Data are quarterly and run mainly from 1975 to 2002/3, and were sourced from the OECD and Eurostat. There are two basic sources for quarterly data on sectoral output prices, with a sufficient time span. The OECD Statistical Compendium 2004-2 "Indicators of Activities for Industry and Services ISIC Rev.3" (ceased end 2001) was used to extract producer prices (1995=100) for the countries of interest – Denmark, Germany, Finland, Ireland, Netherlands, Sweden, UK and on the US price as the 'world price'. These were available as a domestic price index constructed in national currency. Corresponding domestic producer price indices at the sectoral level (NACE code) were available from EUROSTAT from 1990 onwards (reference IO7qprin). The OECD series was used after updating with the appropriate rate of change in the price from the corresponding price series up to quarter 4, 2004.

The domestic manufacturing wage for the entire period is available from the OECD and is calculated as a quarterly index of hourly earnings (2000=100) in all manufacturing for each country. Sectoral specific wage rates were not available. Owing to the index form of the data, measures such as the Lerner Index are not estimated.

The exchange rates used were obtained from EUROSTAT (Ameco) and are represented as a quarterly average where one DM, US dollar or SEK is equal to so many units of domestic currency. Post Euro values were converted back to domestic currencies existing prior to the introduction of the Euro in order to achieve a consistent exchange rate time series.

The following time series are analysed for the 30-year period Q1 1975 to Q4 2004:

XXCHEMPR : domestic producer price for Chemicals (1990=1)
XXBASMETPR : domestic producer price for Basic Metals (1990=1)
XXFBTPR : domestic producer price for Food, Beverages and Tobacco (1990=1)
XXNMETPR : domestic producer price for Non-metallic Mineral Products (1990=1)
XXPAPPR : domestic producer price for Paper and Paper Products (1990=1)
XXWOODPR : domestic producer price for Wood and Wood Products (1990=1)
XXUSD : 1 US dollar = units of domestic currency
XXDE : 1 German Deutschmark = units of domestic currency
XXSW : 1 Swedish Kroner = units of domestic currency
Where XX = DE, DK, FI, IE, NL, SW, UK, US

DEMANW : All manufacturing manual wage index for Germany
DKMANW : All manufacturing manual wage index for Denmark
FIMANW : All manufacturing manual wage index for Finland
IEMANW : All manufacturing manual wage index for Ireland
NLMANW : All manufacturing manual wage index for the Netherlands
SWMANW : All manufacturing manual wage index for Sweden
UKMANW : All manufacturing manual wage index for the United Kingdom
All of the above wage rates are in index form, 2000 = 1.000

Data were not to hand for dealing with Pharmaceuticals separately from Chemicals. The data on Food and Drink included Tobacco. Econometric tests are described in Appendix 1. All econometric estimations have been carried out using Eviews 5.0

5. Results

The basic model in (1) above was tested on the data. Table 6a shows the results and significance levels for the three items, $\boldsymbol{\lambda}$ (the speed of adjustment), domestic cost (own country manufacturing wage) and foreign output price in US dollars across the six selected sectors and six ETR countries plus Ireland. A measure of fit is given by the adjusted R^2.

Table 6b shows the equivalent analysis with the German as opposed to US price used to represent the foreign or competing price.

At the base of each table are two rows headed 'result'. For each sector, these give the number of countries for which the domestic cost and then the foreign price were significant determinants of price. Results are now discussed for each sector followed by overall implications.

(Table 6a)

(Table 6b)

6. Discussion of Results by Sector

Chemicals

For this sector, there is a better fit generally when the German rather than the US price is used to represent the foreign price. The long-run relationship, as measured by λ, was found to be significant for most countries with a few exceptions. For Sweden the long-run relationship holds only when the German price is used (at 10% level), and for the Netherlands only when the US price is used.

Turning to the actual strength of domestic versus foreign influences on the output price, results in Table 6a are somewhat mixed for this sector. The US price is found to influence chemicals output prices only in the Netherlands (quite strongly) and in Ireland. By contrast in Germany in particular and in Ireland too the results suggest that domestic costs have a significant influence, Ireland being influenced by both the US price and domestic costs.

In Table 6b, where the German price was used as the potential foreign price determinant, Sweden and the UK are found to respond to this price, having not responded to the US price. Ireland responds to both foreign prices. Domestic costs are not significant determinants in any country in Table 6b. The speed of adjustment is generally higher where the German as opposed to US price plays the role of external price.

This sector could be vulnerable under an environmental tax regime in certain countries, namely, in the Netherlands and in Ireland, which showed clear signs of being price-takers of the US price. The influence of the German price in Sweden, the UK and also in Ireland suggests that the sector is a price-taker on the 'EU market'. However if ETR were applied on an EU-wide basis, it would affect EU 'competing' countries in a consistent manner, reducing vulnerability.

Food, Beverages and Tobacco

For this sector the fit is somewhat improved when the foreign price is represented by the German as opposed to the US price. The adjustment coefficient is also marginally stronger and more significant, though Germany, Finland and Sweden are poorly modelled by this long-run relationship in general, regardless of the foreign price used. Turning to the influences on the domestic output price in Table 6a, only results for Denmark suggest an influence from the US price, though with only 10% significance, while results for Ireland, the UK (quite strongly) and the Netherlands indicate that domestic costs dominate.

In Table 6b the German price can be viewed as a proxy for the effect of the Common Agricultural Policy on a large share of this sector's prices. We find here that output prices in Denmark and the UK respond to this 'EU price', having not responded to the US price in Table 6a. The UK and the Netherlands show domestic costs exerting a strong influence on their price-setting regimes. There does not appear to be broad vulnerability to environmental tax reform if applied at EU level therefore. The UK is an example of the third type of outcome mentioned above, where both domestic costs and the foreign (German) prices are significant so that the sector is both price-taker with respect to European prices, and price-setter. Were further sectoral disaggregation of data possible it might clarify this situation.

Non-metallic Mineral Products

This sector is not highly traded and the US price, when used to represent the foreign price, is nowhere significant in explaining movements in the sector's output price. In the UK in particular the model shows domestic costs as a determinant. If the sector responds to any foreign price, it is likely to respond to the German or 'European' price. This reflects the low trade shares owing to the bulky nature of the product and its high weight-to-value ratio.

In Table 6b, where the external price is represented by the German price, the outcome however is an inferior fit and the German price is only significant in the Netherlands and to a minor extent in Finland. Domestic costs on the other hand significantly determine a substantial portion of this sector's output price in all countries investigated. To the extent that the external price is at all significant, the fact of it being the German price indicates that a carbon-energy tax applied EU-wide would not create significant competitive disadvantage, given that the rest of the EU would face a similar tax.

Paper and Paper Products

In this sector we find that a better fit with revealed behaviour is shown when the foreign price is represented by the German price, rather than by the US price. Nevertheless, Sweden and Germany, and the Netherlands to a minor extent, show a significant impact from the US price, an impact which is large in the case of Sweden according to Table 6a. In Germany's case, domestic costs also have a significant and more dominant impact, a pattern also prevailing in the Netherlands.

Taking the German price as the foreign price in Table 6b, we find that in size terms and where significant, the external price dominates the influence of domestic cost.

This is particularly the case in Sweden where the relationship with the German price is stronger than with the US price, and in Denmark and the UK. This supports the view that this highly traded sector is a price-taker. But, with minor exceptions in Germany and the Netherlands where the US price is partially influential, the effect on competitiveness would be reduced if ETR applied across all of the EU.

Wood and Wood Products

The findings for wood and wood products also show that a better fit is generally obtained using the German rather than the US price. In all cases that use the German price the adjustment coefficient is significant, at least at the 5% level. The results for Sweden may be anomalous. For the other countries examined the coefficient on domestic costs is highly significant and greater in magnitude than that on the foreign currency price. This suggests a significant degree of market power on the part of firms and an ability to absorb at least some of the incidence of any environmental taxes. The fact that it is the German price rather than that of the US which provides better explanatory power in the equations suggests that where an environmental tax regime (or emissions trading regime with auctioning) is introduced on an EU-wide basis there would be little effect on the competitiveness of domestic output. All firms supplying the EU market would be affected in a consistent manner.

Basic Metals

In the basic metals sector the US price has a strong and significant influence on output prices except in the cases of Germany and Ireland. An even stronger external price effect is found when using the German price as the external price, and this sector is evidently a price-taker on world markets as results indicate that this sector's pricing is the most responsive to both sets of external prices. Bar the case of Ireland where neither foreign price has an impact, the German price is a more important determinant of the output price and far outweighs the influence of domestic costs, which in Table 6a are of lesser significance and in fact insignificant in the case of Sweden. The exceptions, where domestic costs are significant at the 1% level, are the 'insular' countries, UK and Ireland, though the magnitude of the effect of domestic costs is still smaller than that of the German price. This indicates that consistent application of environmental tax reform across the EU could temper the effect on competitiveness. The adjustment coefficient suggests a relatively strong and significant stable long-run pattern of response across all the countries studied.

7. Implications

This analysis of price setting by the selected sectors across ETR countries produced plausible results with good explanatory power. Two prices were employed to represent the foreign or competing price, the US price and the German price. Use of the German price generally fitted the data better than when the US price was used. In the case of the Non-metallic mineral products sector, it was only the German price that had a significant 'foreign' influence on price-setting. That applied only in the Netherlands and to a very small extent in Finland, putting this sector at the least vulnerable end of the price-setting spectrum. By contrast Basic metals revealed the most influence from the foreign price and was more likely to be a price-taker and hence vulnerable under domestic cost increases that emanated from environmental tax reform.

Importantly, the results also showed that use of the German price was in general more consistent with a stable long-run price-setting relationship. Information on trade with the EU, shown in tables 4 and 5 above, indicated the predominance of the EU as the source and destination for the products of the selected sectors during the period over which environmental tax reform was being introduced. Therefore the indications are that environmental tax reform introduced on an EU-wide basis (or emissions trading with auctioning) would have a limited effect on the competitiveness of these sectors because all firms supplying the EU market would be affected in a consistent manner.

These time-series regression results can be employed to rank the selected sectors according to decreasing significance of the external price, that is, in decreasing order of vulnerability or, correspondingly, in increasing order of market power. Thus ranked the sectors are as follows, starting with the most vulnerable:

1. Basic metals
2. Paper and paper products

3. Wood and wood products
4. Chemicals
5. Food, beverages and tobacco, and
6. Non-metallic mineral products.

Basic metals were very susceptible to international trading conditions and would be the most affected by an energy or carbon tax. This of course is in the absence of mitigating or other measures, such as targeted revenue recycling, technical adaptations, waivers, border tax adjustments and the like, discussed in COMETR (2007). The sector would face a cost disadvantage compared with its trading partners and would not be in a position to mark up its price. At the other extreme, the Non-metallic mineral products sector responded very closely to domestic costs (wage costs in this analysis) and appeared to be relatively insulated from international trading conditions. The study did not show the world price, proxied by the US price, to have any influence. Of the sectors analysed, Non-metallic mineral products would be best placed to absorb a cost increase such as from carbon or energy taxes, by passing on the tax to its (mostly domestic) customers in the form of higher product prices. Sectors able to make worthwhile alterations to their technology would be better placed still.

While we have established a hierarchy of sectors in terms of their potential vulnerability to environmental tax reform this hierarchy only holds within a reasonable range of tax rates. It is always possible that in the event of a large rise in tax rates affecting firms' energy prices, firms that were previously price setters might become price takers. However, it would take a very sizable rise in tax rates to bring this about.

It is now possible to add the ranking of price-setting power to the criteria used at the outset to gauge a sector's vulnerability under environmental tax reform. A few examples of combined rankings under various criteria are now shown to give a more comprehensive view of the relative vulnerability of sectors. It is noted that the criteria are what the Carbon Tust (2004) terms 'competitiveness drivers' in relation to the EU ETS.

Figure 1 below illustrates the situation when unit energy costs and pricing-power are taken together as two criteria of vulnerability for the combined ETR countries. The vertical axis shows increasing energy expenditure as a share of output, and the horizontal axis shows increasing market power, that is, decreasing foreign price influence in price-setting. Vulnerability is highest in the top left-hand corner where the energy share is highest and price-setting ability is lowest. Vulnerability is lowest in the bottom right-hand corner.

On these criteria, the most vulnerable sectors are Basic metals and Chemicals in the top left-hand of the figure. The Chemical sector has the highest energy expenditure share and Basic metals is the most exposed to the world price - it is the least able to pass on cost increases.
(Figure 1)

In the bottom right-hand corner of the figure are the less vulnerable sectors Food, beverages and tobacco and Non-metallic minerals products. Ranked in the middle in terms of vulnerability is the sector Wood and paper.

The implications for policy are that the introduction of ETR would require most care to be paid to its effects on the competitiveness of Basic metals and Chemicals rather than to Non-metallic mineral products, and less again to Food, beverages and tobacco. These rankings of vulnerability apply to the combined six countries that implemented ETR. (Individual country rankings are given in Appendix 2)

As already flagged, a major criterion for vulnerability is the sector's scope for introducing economically worthwhile energy efficiency investments. Though not the core aim of this study, encouragement to the use and development of energy-efficiency is a prime objective and benefit of carbon taxes, and information on potential technical adjustment was sought. Potential technology adjustments that were available to UK energy intensive sectors had been estimated by Entec, under procedures for the Climate Change Agreements. These adjustment potentials can be used here, again for illustrative purposes. Here also the sectors can be ranked, by scope for adjustment measured in percentage energy saving potential at positive NPV, starting with those that have least scope (i.e. the most vulnerable), as shown in Table 7.

(Table 7)

The sectors now ranked according to their technological potential for energy efficiency adjustments can be incorporated into a similar figure, Figure 2, relating to the UK. Alongside ranked vulnerability to price competition is shown ranked vulnerability with respect to scope for technological adjustment.
(Figure 2)

At the extremes, it can be seen that in the UK the Basic metals sector is again clearly in a relatively vulnerable position in the figure, now joined by Wood and wood products. Food, beverages and tobacco and the Non-metallic mineral products sectors are least vulnerable - they have some modest potential for adapting technology and have some price-setting power. Chemicals and Pulp and paper are in between.

These examples give relative placings of sectors and their importance lies in demonstrating that one can rank vulnerability on relevant criteria. They thereby indicate where to prioritise mitigation policies to soften any impact on competitiveness of sectors in the event of environmental tax reform.

8. Conclusions

Six countries EU member states introduced environmental tax reform, in the form of carbon taxes with revenue recycling, during the 1990s and after. The purpose of this paper was to highlight sectors that could be vulnerable under such reform and to explore the nature of their vulnerability. Were they price-takers and, if so, on which markets, and were technological opportunities available that they could call on in order to reduce vulnerability? Initial screening based on intensities of energy expenditure and other characteristics was undertaken for all sectors to select those six in which price-setting behaviour would be investigated.

A price-setting model was posited and applied in order to throw light on the market power of the selected sectors. The results of the analysis were significant and plausible. The importance of these results is that a sector's price-setting ability and hence a major aspect of its relative vulnerability can be realistically assessed.

Among the selected sectors, Basic metals had least market power and Non-metallic minerals had most. Where the foreign price was a constraint on the price setting by sectors, it was the German price that tended to dominate. The significance of this fact is that EU-wide application of environmental tax reform, by contrast with application by individual countries on their own, would give less cause for concern about loss of competitiveness.

Relocation of production is a feared outcome of the introduction of environmental regulations. This highlights the advantages of ETR over environmental regulations for example, because tax revenues are available that can be used to help prevent industrial relocation. This is provided that the revenue recycling is designed and targeted carefully using correct criteria, including the market power criterion described here.

The scope for sectors to make profitable adjustments to their technology also has an important bearing on their vulnerability. Energy-saving investment cost curves can be used to assess each sector's scope for adjusting technology, thereby avoiding the adverse effect of the tax side of ETR.

In the analysis so far it is the Basic metals sector that emerges as being vulnerable consistently on most criteria. This is because it is energy intensive, it is a price-taker on the world market and its scope for adjusting technology is relatively low. A mitigating factor is its high labour intensity, meaning that any labour tax reduction brought about as part of the ETR could be to its benefit. The Chemicals sector shows similar characteristics of vulnerability though its scope for costless technology adjustment may not have been so limited.

The vulnerability of Wood and paper depends on the criteria used. Middling vulnerable on pricing power were Wood and wood products and Pulp and paper, the former being vulnerable on technology options while the latter has scope for adjustments (these apply to the UK). The Non-metallic minerals sector along with Food, beverages and tobacco are the least vulnerable on these criteria.

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Appendix 1 Econometric tests

The test for a unit root is to show whether the data conform to the requirements for the relationship not to be spurious. Appendix Table 1 summarises the results for the price variables of unit root tests on levels and in first differences of the data. Evidence emerges that all the series are generally I(1). They are tested for unit roots and their order of integration using an ADF test. Thus the relationship we seek is a cointegrating one.

A Johansen test strongly rejects the null of no cointegration of the dependent and key independent variables at the 5% level, that is, they tested satisfactorily. Given the result that a unique cointegrating relationship exists, a single equation ECM offers a robust alternative to the Johansen method. Validity is conditional on the regressors being weakly exogenous, but we show that this condition is satisfied. (In a cointegrated system, if a variable does not respond to the discrepancy from the long-run equilibrium, it is weakly exogenous, that is, the speed of adjustment parameter is 0.) Thus the estimation can proceed in the single-equation framework. Single equation estimates should be reliable and a well-determined t statistic on the ECM term is further evidence of cointegration. Additional tests for unit roots were undertaken for the price variables, interest focusing on foreign prices that the regressions tested for. Results are shown in Appendix Table 1.

(Appendix Table 1 here)

Appendix 2: Ranking by unit energy costs and market power

This appendix sets out the ranking by decreasing vulnerability in individual ETR countries by looking at energy expenditure shares of value-added alongside market power as measured by foreign price influence.

The model results on market power were used for ranking vulnerability, though this should be viewed as approximate because it is not an exact method. The ranking method was based mainly on the significance and size of the coefficient on the variable Foreign Price in Table 6b, with consideration being given to Table 6a. After variables with significant foreign price coefficients were exhausted, those with significant domestic costs were used to inform the ranking.

(Appendix Table 2 here)

Table 1: EU Countries that introduced carbon/energy tax reforms (ETR countries)

Sweden	1991
Denmark	1995
Netherlands	1996
Finland	1997
Germany	1999
United Kingdom	2001 (announced 1999)

Table 2: Potentially vulnerable sectors selected for analysis

	NACE code
Pulp, paper and board	21
Wood and wood products	20
Basic chemicals excl. pharmaceuticals	24 less 24.4
Pharmaceuticals	24.4
Non-metallic mineral products	26
Basic metals	27
Food and beverages	15

Note: Cement forms a large share of non-metallic minerals. The sector Food and beverages were included as a comparator.

Table 3: Unit energy cost in selected sectors in ETR countries, 1998, % of GVA

	Wood and paper	Pharma-ceuticals	Basic Chemicals	Non-met mineral products	Basic Metals	Food, beverages & tobacco	Total Gross Manuf. Output
Denmark	2.4	3.3	4.8	6.8	17.7	5.4	4.6
W. Germany	7.4	19.9	27.2	15.7	56.3	7.8	6.2
Finland	21.4	14.5	19.7	12.3	33.0	4.0	7.9
Netherlands	4.8	24.0	32.3	11.7	29.6	4.7	7.7
Sweden	8.6	15.2	20.4	16.2	29.4	5.8	4.6
UK	4.4	3.8	12.4	8.8	8.5	3.5	4.9
EU15	8.6	17.3	24.4	17.8	42.5	6.8	7.0
ETR (6)	8.0	16.7	24.4	15.0	14.4	6.0	6.5
Non ETR(6)	9.4	18.9	25.3	21.2	36.3	7.7	7.4

Source: Cambridge Econometrics. *Notes:* Annual average exchange rates from Eurostat Ameco database were used. *Basic* prices are defined as the prices received by producers minus any taxes payable plus subsidies received as a consequence of production or sale. The expenditure on energy is made up of the cost in the manufacturing process in each sector of 11 different fuel types: Coal, Coke, Lignite, Heavy Fuel Oil, Middle Distillates, Natural Gas, Derived Gas, Electricity, Nuclear Fuels, Crude oil and Steam.

Table 4: Proportion of exports to EU destinations (average 1990-1998)

	Wood and Paper	Pharma-ceuticals	Basic Chemical	Non-met mineral products	Basic Metals	Food, Beverages & Tobacco	Total Gross Manuf.
Denmark	0.89	0.55	0.54	0.84	0.92	0.70	0.69
W. Germany	0.78	0.63	0.63	0.77	0.69	0.73	0.63
Finland	0.75	0.47	0.46	0.64	0.80	0.39	0.64
Netherlands	1.84	0.67	0.66	0.76	0.76	0.81	0.73
Sweden	0.91	0.81	0.80	0.93	0.87	0.64	0.76
UK	0.61	0.64	0.64	0.56	0.68	0.62	0.64
EU15	0.81	0.66	0.66	0.67	0.75	0.78	0.68

Note: Data recording in the case of pulp and paper for the Netherlands is unreliable.

Table 5: Imports from EU as a share of country imports (average 1990-1998)

	Wood and Paper	Pharma-ceuticals	Basic Chemical	Non-met mineral products	Basic Metals	Food, Beverages & Tobacco	Total Gross Manuf.
Denmark	1.02	0.89	0.89	0.95	0.94	0.68	0.77
W. Germany	0.84	0.78	0.78	0.69	0.66	0.79	0.66
Finland	0.88	0.86	0.86	0.68	0.67	0.81	0.70
Netherlands	0.89	0.76	0.76	0.82	0.77	0.77	0.69
Sweden	0.92	0.86	0.86	0.78	0.75	0.83	0.75
UK	0.83	0.83	0.83	0.64	0.68	0.76	0.67
EU15	0.90	0.86	0.86	0.70	0.73	0.81	0.74

Table 6a: Modelling the domestic output price - with the US price representing the foreign price [1]

-Adjustment speed λ -Domestic cost -Foreign price -Fit: Adjusted R^2	Chemicals	Food, Beverages and Tobacco	Non-metallic Mineral Products	Paper and Paper Products	Wood and Wood Products	Basic Metals
Denmark	-0.128***	-0.050**	0.009	-0.028	-0.045	-0.062**
	0.043	0.164	1.377	0.224	0.421	0.174
	0.137	0.295*	-0.920	0.639	0.151	0.643***
	0.262	0.388	0.540	0.453	0.359	0.323
Germany	-0.137**	-0.012	-0.022	-0.044***	-0.030*	-0.149
	0.381***	0.242	0.079	0.361***	0.517***	0.270
	0.174	0.517	-0.327	0.244***	0.110	1.246
	0.492	0.143	0.498	0.732	0.533	0.598
Finland	-0.135**	-0.010	-0.048**	-0.107**	-0.118***	-0.116***
	0.037	0.745	0.278**	0.285*	0.464***	0.375***
	0.164	0.693	0.056	0.153	0.029	0.301***
	0.306	0.449	0.410	0.484	0.401	0.600
Ireland	-0.127**	-0.075***	-0.041*	-0.087**	-0.150***	-0.400***
	0.143**	0.340***	0.344*	0.659***	0.572***	0.240***
	0.280**	0.182	-0.013	0.061	0.154**	0.017
	0.196	0.455	0.394	0.516	0.487	0.213
Netherlands	-0.152***	-0.091**	-0.016	-0.083**	-0.064*	-0.083**
	0.005	0.349***	0.124	0.338***	0.684***	0.300***
	0.555***	0.123	0.134	0.195*	-0.069	0.405***
	0.580	0.462	0.395	0.582	0.446	0.508
Sweden	-0.063	-0.017	-0.002	-0.045*	-0.034*	-0.038*
	0.092	-1.078	-8.456	0.365	0.268	0.410*
	0.590	1.190	0.027	0.604**	0.263	0.711**
	0.246	0.420	0.727	0.612	0.482	0.634
UK	-0.079*	-0.053***	-0.035***	-0.013	-0.067***	-0.055***
	0.023	0.470***	0.352***	-0.332	0.556***	0.329***
	0.050	0.063	0.260	0.629	0.089	0.267*
	0.195	0.547	0.730	0.742	0.656	0.700
RESULT (no. of significant price determinants in sector)	2 Domestic	3 Domestic	3 Domestic	4 Domestic	5 Domestic	5 Domestic
	2 US	1 US	0 US	3 US	1 US	5 US

[1] Using US$ exchange rates and imposing PPP. * Significant at 10%, ** Significant at 5%, *** Significant at 1% level.

Table 6b: Modelling the domestic output price - with the German price representing the foreign price [2]

-Adjustment speed λ -Domestic cost -Foreign price -Fit: Adjusted R^2	Chemicals	Food, Beverages and Tobacco	Non-metallic Mineral Products	Paper and Paper Products	Wood and Wood Products	Basic Metals
Denmark	-0.175*** 0.007 0.389 0.454	-0.122*** -0.134* 1.003*** 0.429	-0.234*** 0.513*** 0.139 0.211	-0.113*** 0.258*** 0.636*** 0.562	-0.100*** 0.458*** 0.358*** 0.420	-0.156*** 0.079* 0.866*** 0.500
Germany	..	..	..	..	..	..
Finland	-0.154*** 0.112 0.210 0.670	-0.003 0.327 -6.157 0.479	-0.315*** 0.419*** 0.053** 0.227	-0.063*** 0.197 0.501 0.555	-0.069*** 0.365** 0.186 0.389	-0.136*** 0.194** 0.516*** 0.643
Ireland	-0.156*** 0.097 0.559* 0.172	-0.050** 0.327 0.069 0.472	-0.269*** 0.438*** -0.100 0.117	-0.095** 0.429*** 0.500** 0.580	-0.072** 0.403*** 0.374* 0.535	-0.276*** 0.209*** 0.294 0.228
Netherlands	-0.034 1.610 -1.874 0.758	-0.098*** 0.847* -1.333 0.481	-0.177*** 0.406*** 0.412*** 0.178	-0.031 0.624 0.320 0.833	-0.093** 0.703*** 0.065 0.461	-0.139*** 0.146** 0.665*** 0.605
Sweden	-0.071* 0.082 1.048* 0.579	+0.011 3.063 -1.113 0.553	-0.176* 0.716*** 0.018 0.257	-0.079*** -0.013 1.036*** 0.667	-0.029** -0.342 0.806* 0.587	-0.124*** 0.047 0.942*** 0.830
UK	-0.113** -0.136 0.436* 0.540	-0.056*** 0.306*** 0.376** 0.628	-0.167** 0.518*** -0.000 0.216	-0.020** -0.167 0.670** 0.774	-0.049*** 0.324*** 0.274*** 0.760	-0.115*** 0.229*** 0.476*** 0.830
RESULT (no. of significant price determinants in sector)	0 Domestic 3 German	3 Domestic 2 German	6 Domestic 2 German	2 Domestic 4 German	5 Domestic 4 German	5 Domestic 5 German

[2] Using DM exchange rates and imposing PPP. * Significant at 10%, ** Significant at 5%, *** Significant at 1% level.

Table 7: Ranking of sectors with respect to scope for technological adjustment, UK 1995 (with NACE code)

20+36	Wood and wood products	(least scope, most vulnerable)
27	Basic metals	
24	Chemicals	
26	Non-metallic mineral products	
15	Food and beverages	
21	Pulp, paper and paper products	(most scope, least vulnerable)

Source: Entec/Cambridge Econometrics, 2003

Appendix Table 1: Unit Root Tests

	Level	First Differences
	ADF test statistic	ADF test statistic
LDEbasmetpr	-3.315497	-5.986174***
LDKbasmetpr	-2.689924*	-8.359629***
LFIbasmetpr	-1.568949	-6.104499***
LIEbasmetpr	-0.343549	-5.547648***
LNLbasmetpr	-2.598586*	-6.701238***
LSWbasmetpr	-1.871067	-5.493550***
LUKbasmetpr	-3.237086**	-4.188560***
LUSbasmetpr	-3.189334**	-3.401767***
LDEchempr	-1.330966	-4.915669***
LDKchempr	-2.962546**	-7.000909***
LFIchempr	-2.212823	-6.790495***
LIEchempr	-3.452354***	-6.803949***
LNLchempr	-3.159378**	-5.440110***
LSWchempr	-1.996497	-6.833328***
LUKchempr	-3.897648***	-7.34932***
LUSchempr	-0.439414	-5.204615***
LDEfbtpr	-1.855558	-5.190388***
LDKfbtpr	-4.054082***	-7.484247***
LFIfbtpr	-4.326288***	-3.774157***
LIEfbtpr	-4.104027***	-2.838678**
LNLfbtpr	-1.469798	-4.694399***
LSWfbtpr	-3.247706**	-2.765823*
LUKfbtpr	-4.929782***	-2.587562*
LUSfbtpr	-2.012392	-4.839287***
LDEnmetpr	-1.954511	-2.406641
LDKnmetpr	-3.013959**	-1.791162
LFInmetpr	-6.842790***	-4.144532***
LIEnmetpr	-6.652777***	-2.941475**
LNLnmetpr	-2.355987	-2.109424
LSWnmetpr	-3.669447***	-2.504838*

LUKnmetpr	-5.059891***	-2.759671**
LUSnmetpr	-1.992435	-1.908696
LDEpappr	-2.093627	-5.394902***
LDKpappr	-2.953416**	-3.220020***
LFIpappr	-2.021902	-5.405187***
LIEpappr	-3.470909**	-5.316844***
LNLpappr	-1.118458	-4.005505***
LSWpappr	-1.641998	-4.828684***
LUKpappr	-4.850024***	-4.230459***
LUSpappr	-2.462221	-4.873529***
LDEwoodpr	-3.409769**	-2.037768
LDKwoodpr		-3.083240***
LFIwoodpr	-3.095870**	-5.883673***
LIEwoodpr	-4.413811***	-5.580623***
LNLwoodpr	-2.435048*	-3.394687**
LSWwoodpr	-3.588209***	-4.895384***
LUSwoodpr	-2.135125	-3.561840***
LUKwoodpr	-4.660079***	-3.139922**

Critical values: 1% level = -3.48655; 5% level = -2.886074; 10% level = -2.579931.

Note: ADF is the Augmented Dickey-Fuller Test for unit roots. The null hypothesis that the series is not stationery is rejected if the test statistic exceeds the critical value in absolute terms. The lag length is based on the Schwarz Information Criterion.

Appendix Table 2 Ranking of vulnerability

DENMARK: (the most vulnerable sectors are at the top of each column)

Expenditure shares	Foreign price influence
Basic metals	Food beverages and tobacco
Non-metallic mineral products	Basic metals
Food beverages and tobacco	Paper
Wood + Paper	Non-metallic minerals

Note: Wood and wood products and Chemicals are not well-modelled and are therefore omitted. In the expenditure shares Wood is included with Paper.

WEST GERMANY:

Expenditure shares	Foreign price influence
Basic chemicals	Paper
Pharmaceuticals	Chemicals
Wood + Paper	Wood

Note: The shaded sectors are those where the issue of different classification between the two columns arises. Where the sectors are contiguous consistency can be maintained by amalgamation.

FINLAND:

Expenditure shares	Foreign price influence
Basic metals	Basic metals
Wood + Paper	Non-metallic mineral products
Non-metallic mineral products	Wood

NETHERLANDS

Expenditure shares	Foreign price influence
Basic chemicals	Basic metals
Basic metals	Chemicals
Pharmaceuticals	Non-metallic mineral products
Non-metallic minerals	Paper
Wood + Paper	Food beverages and tobacco
Food beverages and tobacco	Wood

SWEDEN

Expenditure shares	Foreign price influence
Basic metals	Paper
Basic chemicals	Basic metals
Non-metallic mineral products	Chemicals
Pharmaceuticals	Wood
Wood + Paper	Non-metallic mineral products

UK

Expenditure shares	Foreign price influence
Basic chemicals	Basic metals
Non-metallic mineral products	Paper
Basic metals	Wood
Wood + Paper	Chemicals
Pharmaceuticals	Food beverages and tobacco
Food beverages and tobacco	Non-metallic mineral products

EU-ETR

Expenditure shares	**Foreign price influence**
Basic chemicals 1	Basic metals 1
Pharmaceuticals “	Paper 2
Non-metallic mineral products 2	Wood “
Basic metals 3	Chemicals 3
Wood + Paper 4	Food beverages and tobacco 4
Food beverages and tobacco 5	Non-metallic mineral products 5

It is the ranking from this last table that is used for the energy/pricing power vulnerability figure in the main text.

Figure 1: Vulnerability with respect to energy expenditure shares and pricing power, ETR countries combined

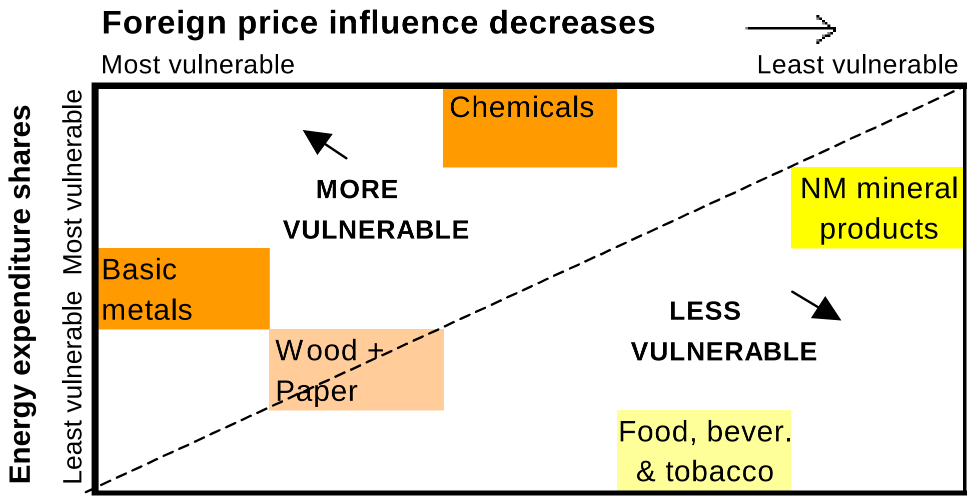
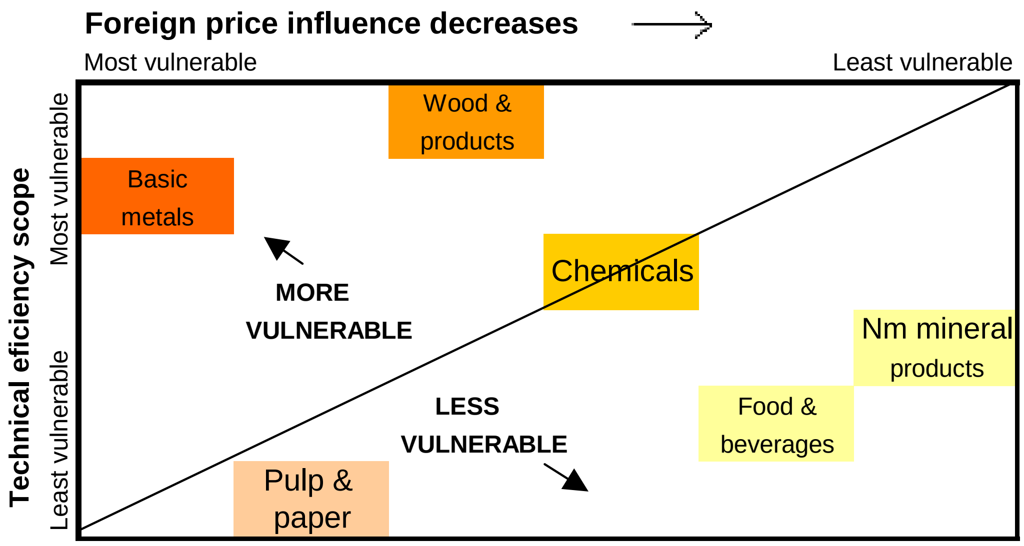


Figure 2: Vulnerability with respect to scope for technology adjustments and pricing power, UK



CAPTIONS

Table 1: EU Countries that introduced carbon/energy tax reforms (ETR countries)

Table 2: Potentially vulnerable sectors selected for analysis

Table 3: Unit energy cost in selected sectors in ETR countries, 1998, % of GVA

Table 4: Proportion of exports to EU destinations (average 1990-1998)

Table 5: Imports from EU as a share of country imports (average 1990-1998)

Table 6a: Modelling the domestic output price - with the US price representing the foreign price

Table 6b: Modelling the domestic output price - with the German price representing the foreign price

Table 7: Ranking of sectors with respect to scope for technological adjustment, UK 1995 (with NACE code)

Appendix Table 1: Unit Root Tests

Appendix Table 2: Ranking of vulnerability

Figure 1: Vulnerability with respect to energy expenditure shares and pricing power, ETR countries combined

Figure 2: Vulnerability with respect to scope for technology adjustments and pricing power, UK

Year	Number	Title/Author(s) ESRI Authors/Co-authors Italicised
2007	221	Climate Policy Versus Development Aid *Richard S.J. Tol*
	220	Exports and Productivity – Comparable Evidence for 14 Countries *The International Study Group on Exports and Productivity*
	219	Energy-Using Appliances and Energy-Saving Features: Determinants of Ownership in Ireland *Joe O'Doherty, Seán Lyons* and *Richard S.J. Tol*
	218	The Public/Private Mix in Irish Acute Public Hospitals: Trends and Implications *Jacqueline O'Reilly* and *Miriam M. Wiley*
	217	Regret About the Timing of First Sexual Intercourse: The Role of Age and Context *Richard Layte*, Hannah McGee
	216	Determinants of Water Connection Type and Ownership of Water-Using Appliances in Ireland *Joe O'Doherty, Seán Lyons* and *Richard S.J. Tol*
	215	Unemployment – Stage or Stigma? Being Unemployed During an Economic Boom *Emer Smyth*
	214	The Value of Lost Load *Richard S.J. Tol*
	213	Adolescents' Educational Attainment and School Experiences in Contemporary Ireland *Merike Darmody, Selina McCoy, Emer Smyth*
	212	Acting Up or Opting Out? Truancy in Irish Secondary Schools *Merike Darmody, Emer Smyth* and *Selina McCoy*
	211	Where do MNEs Expand Production: Location Choices of the Pharmaceutical Industry in Europe after 1992 *Frances P. Ruane*, Xiaoheng Zhang

210	Holiday Destinations: Understanding the Travel Choices of Irish Tourists *Seán Lyons, Karen Mayor* and *Richard S.J. Tol*
209	The Effectiveness of Competition Policy and the Price-Cost Margin: Evidence from Panel Data Patrick McCloughan, *Seán Lyons* and William Batt
208	Tax Structure and Female Labour Market Participation: Evidence from Ireland *Tim Callan,* A. Van Soest, *J.R. Walsh*
207	Distributional Effects of Public Education Transfers in Seven European Countries *Tim Callan,* Tim Smeeding and Panos Tsakloglou
206	The Earnings of Immigrants in Ireland: Results from the 2005 EU Survey of Income and Living Conditions *Alan Barrett* and *Yvonne McCarthy*
205	Convergence of Consumption Patterns During Macroeconomic Transition: A Model of Demand in Ireland and the OECD *Seán Lyons, Karen Mayor* and *Richard S.J. Tol*
204	The Adoption of ICT: Firm-Level Evidence from Irish Manufacturing Industries *Stefanie Haller* and *Iulia Traistaru-Siedschlag*
203	EU Enlargement and Migration: Assessing the Macroeconomic Impacts Ray Barrell, *John Fitz Gerald* and Rebecca Riley
202	The Dynamics of Economic Vulnerability: A Comparative European Analysis *Christopher T. Whelan* and *Bertrand Maître*
201	Validating the European Socio-economic Classification: Cross-Sectional and Dynamic Analysis of Income Poverty and Lifestyle Deprivation *Dorothy Watson, Christopher T. Whelan* and *Bertrand Maître*