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A Cost-Benefit Analysis of the EU 20/20/2020 Package

Richard S.J. Tol

Abstract: The European Commission did not publish a cost-benefit analysis for its 2020 climate package. This paper fills that gap, comparing the marginal costs and benefits of greenhouse gas emission reduction. The uncertainty about the marginal costs of climate change is large and skewed, and estimates partly reflect ethical choices (e.g., the discount rate). The 2010 carbon price in the ETS can readily be justified by a cost-benefit analysis. Emission reduction is not expensive provided that policy is well-designed, a condition not met by planned EU policy. It is probably twice as expensive as needed, costing one in ten years of economic growth. The EU targets for 2020 are unlikely to meet the benefit-cost test. For a standard discount rate, the benefit-cost ratio is rather poor (1/30). Only a very low discount rate would justify the 20% emission reduction target for 2020.

Key words: European Union; climate policy; cost-benefit analysis

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A Cost-Benefit Analysis of the EU 20/20/2020 Package

1. Introduction
The European Union aims to limit its 2020 greenhouse gas emissions to 80% of its 1990 emissions (European Parliament and Council of the European Union 2009a; European Parliament and Council of the European Union 2009c) and to meet 20% of its energy needs by renewables (European Parliament and Council of the European Union 2009b). The European Commission has published an impact assessment (CEC 2008a; CEC 2008b), but not a cost-benefit analysis – an earlier cost-benefit analysis (CEC 2005a; CEC 2005b) covered the eventual target but not the intermediate ones, let alone the details of policy implementation. This paper fills the gap, estimating the costs and the benefits of reducing greenhouse gas emissions by 20% in a decade.¹

Climate policy is one of the cornerstones of the European Union. It seeks to be a world leader in this area, an ambition which is broadly supported by the public (TNS Opinion and Social 2009). The “climate and energy package” for 2020 implements European climate policy in the medium-term. The Emissions Trading System (ETS) for carbon dioxide will be expanded in scope, the cap will be tightened, and permits will increasingly be auctioned. There are, for the first time, firm targets for greenhouse gas emissions outside the ETS. There are targets for the market share of renewable energy too. These policies will raise the price of energy, slow down economic growth, and reduce welfare. In return, emissions will fall, climate will change less, and the impacts of climate change will be reduced. It is reasonable to ask whether the benefits – i.e., the avoided damages of climate change – outweigh the costs. Maybe European climate policy is too ambitious, or maybe it is not ambitious enough.

The results of cost-benefit analyses should always be interpreted with care, because estimates of the costs and the benefits of an intervention are never complete and rarely do justice to the complexity of the situation (Pearce 1976). These problems are

¹ Note that total emissions in 2008 were very close to those in 1990. Note also that EU emissions were reasonably stable because emissions are increasingly outsources to other countries, particularly in Asia (Davis and Caldeira 2010; Helm et al. 2007; Peters 2008; Peters and Hertwich 2008a; Peters and Hertwich 2008b; Yunfeng and Laike 2010)
particularly pronounced for evaluations of such problems as climate change, which is
global, diffuse, unequal, long-lived, and uncertain (van den Bergh 2004). Nevertheless, cost-benefit analysis is far superior as a guide to good policy than the
hand-waving practised by some politicians. The results of this paper should therefore
be treated with caution but not dismissed out of hand.

The analysis in this paper is about climate change. The policy package also refers
to the benefits of improved energy security, higher employment, and accelerated
innovation. I do not attempt to quantify these benefits, or even argue about the likely
sign.

In Section 2, I survey the economic impacts of climate change. In Section 3, I
study the impacts of greenhouse gas emission reduction. In Section 4, I combine the
two in a cost-benefit analysis of the EU 20/20/2020 package. Section 5 concludes.

2. Benefits of climate policy
(Tol 2009b) reviews the total economic impacts of climate change. There are positive
and negative impacts of climate change. Positive impacts dominate in the short run
(when climate change is largely beyond human control), but negative impacts
dominate in the medium and long run. Impact estimates are uncertain, incomplete and
controversial but the available evidence suggests that a century of climate change is
most likely about as bad as losing one year of economic growth and probably less bad
than losing a decade of growth. In the course of decade, the European Union can only
have a small effect of climate change. Therefore, estimates of the marginal damage
costs are more relevant than estimates of the total damage costs.

The marginal damage cost of carbon dioxide, also known as the “social cost of
carbon,” is defined as the net present value of the incremental damage due to a small
increase in carbon dioxide emissions. For policy purposes, the marginal damage cost
(if estimated along the optimal emission trajectory) would be equal to the Pigouvian
tax that could be placed on carbon, thus internalizing the externality and restoring the
market to the efficient solution.

(Tol 2009b) reports 47 studies with 232 estimates of the social cost of carbon.
Table 1 shows some characteristics of a meta-analysis of the published estimates of
the social cost of carbon. One key issue in attempting to summarize this work is that
just looking at the distribution of the medians or modes of these studies is inadequate,
because it does not give a fair sense of the uncertainty surrounding these estimates – it
is particularly hard to discern the right tail of the distribution which may dominate the policy analysis (Tol 2003; Tol and Yohe 2007; Weitzman 2009). Because there are many estimates of the social cost of carbon, this can be done reasonably objectively. The idea here is to use one parameter from each published estimate (the mode) and the standard deviation of the entire sample—and then to build up an overall distribution of the estimates and their surrounding uncertainty on this basis using the methodology in (Tol 2008). The results are shown in Table 1.

Table 1 reaffirms that the uncertainty about the social costs of climate change is very large. The mean estimate in these studies is a marginal cost of carbon of €49 per metric tonne of carbon dioxide, but the modal estimate is only €14/tCO₂ – close to the EU ETS price of €15/tCO₂. Of course, this divergence suggests that the mean estimate is driven by some very large estimates—and indeed, the estimated social cost at the 95th percentile is €185/t CO₂ and the estimate at the 99th percentile is €439/t CO₂.

This large divergence is partly explained by the use of different pure rates of time preference in these studies. Table 1 divides up the studies into three subsamples which use the same pure rate of time preference. A higher rate of time preference means that the costs of climate change incurred in the future have a lower present value, and so for example, the mean social cost of carbon for the studies with a 3 percent rate of time preference is €5/ tCO₂, while it is €76/ tCO₂ for studies that choose a zero percent rate of time preference. But these columns also show that even when the same discount rate is used, the variation in estimates is large. Table 1 shows that the estimates for the whole sample are dominated by the estimates based on lower discount rates.

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2 I fitted a Fisher-Tippett distribution to each published estimate using the estimate as the mode and the sample standard deviation. The Fisher-Tippett distribution is the only two-parameter, fat-tailed distribution that is defined on the real line. A few published estimates are negative, and given the uncertainties about risk, fat-tailed distributions seem appropriate (Tol 2003; Weitzman 2009). The joint probability density function follows from addition, using weights that reflect the age and quality of the study as well as the importance that the authors attach to the estimate — some estimates are presented as central estimates, others as sensitivity analyses or upper and lower bounds. See [http://www.fnu.zmaw.de/Social-cost-of-carbon-meta-analy.6308.0.html](http://www.fnu.zmaw.de/Social-cost-of-carbon-meta-analy.6308.0.html)

3 Note that the estimates with a discount rate of zero percent are not much higher than the estimates with a discount rate of 1%. The main reason is that most estimates are (inappropriately) based on a finite time horizon. With an infinite time horizon, the social cost of carbon would still be finite, because fossil fuel reserve are finite and the economy would eventually equilibrate with the new climate, but the effect of the zero discount rate would be more substantial. For the record, there is even one estimate (Hohmeyer and Gaertner 1992) based on a zero consumption discount rate (Davidson 2006; Davidson 2008) and thus a negative pure rate of time preference.
Although Table 1 reveals a large estimated uncertainty about the social cost of carbon, there is reason to believe that the actual uncertainty is larger still. First of all, the social cost of carbon derives from the total economic impact estimates – and I argue above that their uncertainty is underestimated too. Second, the estimates only contain those impacts that have been quantified and valued – and I argue below that some of the missing impacts have yet to be assessed because they are so difficult to handle and hence very uncertain. Third, although the number of researchers who published marginal damage cost estimates is larger than the number of researchers who published total impact estimates, it is still a reasonably small and close-knit community who may be subject to group-think, peer pressure and self-censoring.

3. Impacts of emission reduction: A survey

The IPCC\(^4\) periodically surveys the costs of emission abatement (Barker et al. 2007; Hourcade et al. 1996; Hourcade et al. 2001); there are the EMF\(^5\) overview papers (Weyant 1993; Weyant 1998; Weyant 2004; Weyant et al. 2006; Weyant and Hill 1999), and there a few recent meta-analyses as well (Barker et al. 2002; Fischer and Morgenstern 2006; Kuik et al. 2009; Repetto and Austin 1997). There are two equally important messages from this literature. First, a well-designed, gradual policy can substantially reduce emissions at low cost to society. Second, ill-designed policies, or policies that seek to do too much too soon can be orders of magnitude more expensive. While the academic literature has focussed on the former, policy makers have opted for the latter.

The costs of emission reduction increase, and the feasibility of meeting a particular target decreases if:

- different countries, sectors, or emissions face different explicit or implicit carbon prices (Boehringer et al. 2006b; Boehringer et al. 2006a; Boehringer et al. 2008; Manne and Richels 2001; Reilly et al. 2006);
- the carbon prices rises faster or more slowly than the consumption discount rate (Manne and Richels 1998; Manne and Richels 2004; Wigley et al. 1996);
- climate policy is used to further other, non-climate policy goals (Burtraw et al. 2003); and
- climate policy adversely interacts with pre-existing policy distortions (Babiker et al. 2003; Parry and Williams III 1999).

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\(^4\) Intergovernmental Panel on Climate Change; [http://www.ipcc.ch/](http://www.ipcc.ch/)

Unfortunately, each of these four conditions is likely to be violated in reality. For instance, only select countries have adopted emissions targets. Energy-intensity sectors that compete on the world market typically face the prospect of lower carbon prices than do other sectors. Climate policy often targets carbon dioxide but omits methane and nitrous oxide. Emission trading systems have a provision for banking permits for future use, but not for borrowing permits from future periods. Climate policy is used to enhance energy security and create jobs. Climate policy is superimposed on energy and transport regulation and taxation.

The costs of emission reduction would also increase if emissions grow faster, if the price of fossil fuels is lower, or if the rate of technological progress in alternative fuels is slower than anticipated. This risk is two-sided. Emissions may grow more slowly, the price of fossil energy may be higher, and the alternative fuels may progress faster than expected.6

There are only a handful of studies that estimate the economic impact of the EU emissions and energy targets for 2020 – roughly, the EU strives for a 20% reduction in greenhouse gas emissions and a 20% share of renewables in total energy supply. The European Commission commissioned an impact assessment (Capros and Mantzos 2000), and the Energy Modeling Forum organised an independent review (Bernard and Vielle 2009; Böhringer et al. 2009a; Böhringer et al. 2009b; Kretschmer et al. 2009). To the best of my knowledge, no Member State ordered a separate impact assessment; and no academic (outside the EMF) studied the implications of the policies.

(Capros and Mantzos 2000) report cost estimates for every single country of the European Union. They report results for a large number of scenarios; I here use two, one that is slightly more economically sophisticated than the actual policy and one that is slightly less sophisticated. (Bernard and Vielle 2009; Kretschmer et al. 2009) and (Bernard and Vielle 2009) report estimates for a number of regions of the EU, while (Boeters and Koornneef 2010) and (Böhringer et al. 2009a) report for the EU as a single region. I assume homogeneity within the modelled regions, that is, every Member State within a region has the same impact as the region as a whole. Thus, there are six estimates for each country.

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6 Note that the rate of technological progress is largely beyond the control of policy makers, at least between now and 2020.
Figure 1 shows the average of the five estimates for the welfare loss per country in 2020. Table 2 has all the results. The EU as a whole would lose 1.3% of welfare, with a range of 0.4% to 4.5%. Spain and Italy would be hit hardest with a mean loss of 1.7%. Belgium and the Netherlands would see positive impacts (when average across the five studies) of 0.1% and 0.2%. Note that 4 out of 5 models estimate a negative effect for these countries. (Bernard and Vielle 2009) are the exception, predicting a substantial improvement in the competitive position of these countries. The Netherlands particularly benefits from a lower oil price (the feedstock for its export-oriented chemical industry) and higher (absolute) margins on transport and re-export. For the EU as a whole, however, climate policy is costly. A loss of 1.3% is of course not dramatic, but it is projected to occur over the space of only eight years (2013-2020), so that roughly one in every ten years of growth is lost. I’ll discuss below whether this investment is justified.

(Böhringer et al. 2009b) show that the 1.3% loss is at least a factor two higher than it could be. This is because of the EU pays lip service only to cost-efficacy in the regulation of greenhouse gas emissions. Particularly, instead of one price for carbon, there are at least 28 prices: one in the ETS, and at least one per Member State for non-ETS emissions. Furthermore, climate policy is also used to serve other policy targets, particularly on renewables and energy security. Besides, climate policy is placed on top of pre-existing regulations.

Figure 2 shows the price of carbon in 2020. Table 3 shows the detailed results. The price in the EU Emissions Trading System (ETS) is some €32/tCO2, with a range from €7/tCO2 to €71/tCO2. The (unweighted) average price outside the ETS is much higher: €75/tCO2. The non-ETS carbon price exceeds €32/tCO2 in four countries: Belgium (€175/tCO2), UK (€126/tCO2), France (€120/tCO2) and the Netherlands (€116/tCO2). Although some Eastern and Southern European countries have been allocated more non-ETS emission rights than they will likely need, the non-ETS price of carbon is zero in one country (Poland) in one model (Bernard and Vielle 2009) only. This is because there is a restricted trade in non-ETS allowances. The non-ETS market price settles on €42/tCO2; this creates a scarcity in all countries and scenarios but one.
4. A benefit-cost analysis of EU climate policy for 2020

4.1. Introduction

To a first approximation, a benefit-cost analysis of greenhouse gas emission reduction policy requires that the marginal costs of emission reduction be equal to the marginal benefits of emission reduction. When evaluating climate policy for a single continent over an eight year period, the approximation is in fact fairly accurate.

Note that EU emissions are a small and shrinking fraction of global emissions. Therefore, emission reduction in the EU only, and only between 2013-2020, necessarily has a minimal effect on climate change and its impacts. This argument is irrelevant, however, as it militates against any long-term investment programme. For example, by the same reasoning, it is pointless to teach children how to write the letter “a” as it is useless without the rest of the alphabet, or if no other children would learn how to read and write. Emission reduction by any jurisdiction in any legislative period necessarily has a small effect. That is no reason not to do it. It is a reason, though, to evaluate costs and benefits at the margin.

4.2. Marginal costs and benefits

Section 2 estimates the marginal damage costs of climate change. Section 3 estimates the marginal costs of emission reduction in the EU. The question whether EU policy passes the benefit-cost test is, at first sight, simply a matter of comparing the two estimates. However, there are complications. Firstly, EU policy is not cost-effective. The same target can be met at a much lower cost (Böhringer et al. 2009b). As cost-effectiveness is a condition for efficiency, this alone means that EU policy fails the benefit-cost test. I therefore compare the marginal damage costs of climate change (Table 1) to the marginal abatement costs for the ideal policy (Table 3, bottom row) rather than for the actual policy.

Secondly, both marginal costs and marginal benefits are rather uncertain. I therefore compute the probability that EU policy meets the benefit-cost test. I take the probability density function of the marginal damage costs of climate change from (Tol 2009a). Table 1 displays some of the characteristics. Note that, for this study, I converted the estimates of the social cost of carbon to 2007 Euro per tonne of carbon dioxide.

I derive the probability density function of the marginal abatement costs in the same manner as (Tol 2009a) derived the uncertainty about the social cost of carbon.
Each of the six estimates of the marginal abatement costs in Table 3 is assumed to be the central estimate of a Normal distribution.\(^7\) The standard deviation of each of the six estimates is assumed to be equal to the standard deviation between the six estimates. The joint probability density is the rescaled sum of the individual probability densities.\(^8\) See Figure 3.

As the probability densities of the marginal abatement costs and the marginal damages costs are mutually independent, the bivariate probability density is the outer product of the two. The chance of meeting the benefit-cost test is then the integral over the bivariate probability density under the condition that the marginal abatement costs is less than or equal to the marginal damage cost.

If all estimates of the marginal damage costs are used, there is a chance of 43% that the benefit-cost test is met (cf. Table 4). If only estimates with a zero percent pure rate of time preference are used, this chance increases to 60%. It falls to 26% for a one percent pure rate of time preference, and to 4.5% for a three percent pure rate of time preference. EU climate policy can be justified by great care for the future (i.e., a low discount rate) and by substantial aversion to risk (i.e., accepting a low probability of passing the benefit-cost test).

### 4.3. Total costs and benefits

Table 4 also shows the expected value of the benefits, which follows from the bivariate distribution of absolute abatement\(^9\) (Figure 3) and social cost of carbon. The expected benefit varies between 7 and 102 billion euro, depending on the pure rate of time preference assumed (if any). The expected cost is 209 billion euro, 1.3% of projected GDP in 2020,\(^10\) if emission abatement is implemented as planned. The benefit-cost ratio ranges between 0.03 and 0.49. If emission abatement is implemented in the cost-effective manner, expected costs fall to 116 billion euro, 0.7% of GDP. The benefit-cost ratio increases to between 0.06 and 0.88.

\(^7\) Unlike the impacts of climate change, there is no reason to believe that the uncertainty about the costs of emission reduction is asymmetric or fat-tailed.

\(^8\) Vote-counting as used here, while not entirely appropriate, leads to a wider spread than using Bayes’ rule.

\(^9\) The distribution of absolute abatement is constructed as above: there are four best guesses, one each from the four models; the standard deviation of each best guess is assumed to be equal to the standard deviation between the best guesses; each individual estimate is assumed to be normally distributed; and the joint distribution is based on aggregating and rescaling the individual distributions.

\(^10\) The models were all calibrated to the same scenario of economic and population growth.
At first sight, the benefit-cost ratios seem to be at odds with the estimated probabilities of meeting in the benefit-cost test, also displayed in Table 4. This illustrates the third problem with doing a benefit-cost analysis of a regional solution to a global problem. The results of the marginal/probability and total/expected cost analysis deviate from one another because the former implicitly assumes that the same carbon tax is applied outside the EU whereas the latter only considers the costs and benefits of emission reduction in Europe – that is, the benefits of emission reduction elsewhere are omitted. Equating the marginal costs of emission reduction to the marginal benefits would increase welfare – if the Pigou tax is applied to all emissions. However, only European emissions are regulated. Therefore, the benefits are only a fraction of the benefits of a global abatement policy – but the costs to Europe are the same.\footnote{In fact, costs are higher because of leakage (Bernard and Vielle 2009).}

4.4. The optimal level of abatement

Cost-benefit analysis would recommend that level of emission abatement for which the expected marginal damage cost equals the expected marginal abatement cost.\footnote{Assuming, as above, that all emissions are regulated.} The latter is difficult to ascertain as much of the variation between my six estimates of the marginal abatement costs is explained by differences in the no-additional-climate-policy scenarios used by the models. Therefore, I do the cost-benefit analysis separately for each model. I assume that the abatement cost curve is quadratic in emission reduction from baseline. The marginal abatement cost curve is therefore linear, and the “optimal” abatement level follows from rescaling the abatement level used by each model.

Table 5 shows the results. The EU target is to cut 2020 emissions to 20% below 1990 emissions. This implies a cut of 19% to 30% below baseline emissions, depending on the model. If the pure rate of time preference is 3% per year, the target falls to 1.4-2.5% from the base year (1990), which is 1.6-2.7% from the baseline. For a 1% pure rate of time preference, the optimal target is 6.9 to 12% from base year (7.6 to 13% from baseline). For a 0% pure rate of time preference, the optimal target exceeds the EU target: 22% to 38% from base year (24% to 42% from baseline). If all estimates of the social cost of carbon are considered regardless of the discount rate,
two models suggest that the EU target is too stringent and two models suggest that it is too lenient. The optimal target is 14% to 24% from base year (15% to 27% from baseline). As above, the EU emission reduction targets can be justified only with a low discount rate.

5. Discussion and conclusion
In this paper, I survey the marginal impacts of climate change and the (marginal) impacts of greenhouse gas emission reduction, particularly in the European Union. I then bring the two strands together in a cost-benefit analysis of the EU targets for 2020. The marginal costs of climate change are uncertain, with negative surprises more likely than positive surprises. Estimates also depend on ethical choices, such as the discount rate. A modest carbon tax can be easily justified. The current carbon price in the ETS is well within the range of available estimates. Emission reduction can be done cheaply, but this requires that emissions gradually deviate from the baseline scenario and that policy is well-designed and takes account of previous regulations. I find that planned EU policy does not meet these conditions. It is twice as expensive as needed, and would cost the equivalent of one in ten years of economic growth.

Comparing the orders of magnitude of the costs of emission reduction and the impacts of climate change suggests that the EU emissions targets for 2020 are not likely to meet the benefit-cost test. Indeed, for a standard discount rate, the benefit-cost ratio is rather poor (1/30). The EU targets become more attractive if policy implementation would be improved or if substantial weight would be placed on the remote future, but one would need a very low discount rate to justify the 20% emission reduction target for 2020.

As EU climate policy for 2020 cannot stand on its climate merits, could the targets be justified in another manner? There are separate targets for renewable energy, which would promote “energy security”. Energy security is a fluid concept. Wind and solar power are less reliable than thermal power generation. Energy security may also be interpreted as diversification of supply. If so, promoting renewables is a second-best policy. Costs are unnecessarily high, and benefits have yet to be quantified (Roques et al. 2008). Energy security may also be interpreted as reducing the import of energy. Again, promoting renewables is a second-best policy, and costs are higher than needed. Benefits are unquantified – and may actually be negative as is usually the case
with import substitution (Bruton 1998). More informally, politicians regularly argue that climate policy would stimulate economic growth, innovation, and employment. Raising the costs of an essential input to the economy is unlikely to accelerate economic growth (Weyant 1993). Climate policy would redirect innovation rather than enhance it (Smulders and Gradus 1996). While appropriate tax reform may stimulate job creation (Patuelli et al. 2005), actual policies are different. It is therefore unlikely that the EU greenhouse gas emission reduction targets would pass the cost-benefit test even if the scope is widened.

Acknowledgements
All errors and opinions are mine.
Table 1. The mean and standard deviation of social cost of carbon (euro/tonne CO₂) for a Fisher-Tippett distribution fitted to 232 published estimates, and to three subsets of these estimates based on the pure rate of time preference.

<table>
<thead>
<tr>
<th>Fitted distribution (weighted)</th>
<th>All</th>
<th>Pure rate of time preference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Mean</td>
<td>49</td>
<td>76</td>
</tr>
<tr>
<td>StDev</td>
<td>81</td>
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<td>Mode</td>
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<tr>
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<td>35</td>
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<tr>
<td>Median</td>
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<tr>
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<tr>
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<td>177</td>
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<tr>
<td>95%ile</td>
<td>185</td>
<td>206</td>
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<tr>
<td>99%ile</td>
<td>439</td>
<td>265</td>
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</table>
Table 2. The impact of the EU 20/20/2020 package on welfare (%) in 2020.

<table>
<thead>
<tr>
<th>Country</th>
<th>Mean</th>
<th>StDev</th>
<th>PACE</th>
<th>DART</th>
<th>GEMINI-E3</th>
<th>WorldScan</th>
<th>PRIMES</th>
<th>PRIMES</th>
</tr>
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<td>1.6</td>
<td>-0.8</td>
<td>-4.4</td>
<td>-0.5</td>
<td>-0.4</td>
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<td>-2.5</td>
<td>5.8</td>
<td>-0.4</td>
<td>-0.9</td>
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<td>-0.8</td>
<td>-4.4</td>
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<td>-0.4</td>
<td>1.4</td>
<td>1.2</td>
</tr>
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<td>-0.4</td>
<td>0.5</td>
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<td>0.5</td>
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<td>-5.2</td>
<td>-0.5</td>
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<td>-0.3</td>
<td>-0.2</td>
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Table 3. The cost of carbon (€/tCO₂) inside and outside the EU ETS in 2020.

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Sources: PACE (Böhringer et al. 2009a), DART (Kretschmer et al. 2009), Gemini-E3 (Bernard and Vielle 2009), WorldScan (Boeters and Koornneef 2010), PRIMES (Capros et al. 2008); PRIMES appears twice as it published estimates based on an overly optimistic and an overly pessimistic interpretation of the rules on CDM.
Table 4. Cost-benefit analysis of the EU 20/20/2020 package: Four alternative estimates of the social cost of carbon (cf. Table 2), the probability of the EU policy meeting the benefit-cost test, the expected value of the benefit, and the benefit-cost ratio for planned and cost-effective implementation of the EU policy.

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Table 5. *Proposed* (EU) and optimal (all, N%) emission reduction in 2020.

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Figure 1. The 2020 welfare impact (percentage) of the EU 20/20/2020 package per Member State and for the EU as a whole; the bars show the average of six published estimates; the lines indicate the range of results.
Figure 2. The 2020 price of carbon (2005 euro per tonne of carbon dioxide) for the EU 20/20/2020 package per Member State (non-ETS), for the EU one average (non-ETS) and for the Emissions Trading System (ETS); the bars show the average of six published estimates; the lines indicate the range of results.
Figure 3. The probability density functions of the marginal abatement costs and the absolute emission reduction in the EU in 2020.
References


TNS Opinion and Social (2009), Europeans' Attitudes towards Climate Change, Special Eurobarometer, CEC Directorate General Communication, Brussels.


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| 2011 | 366    | The Distributional Effects of Value Added Tax in Ireland  
*Eimear Leahy, Seán Lyons, Richard S.J. Tol* |
| 2010 | 365    | Explaining International Differences in Rates of Overeducation in Europe  
*Maria A. Davia, Seamus McGuinness and Philip, J. O’Connell* |
|      | 364    | The Research Output of Business Schools and Business Scholars in Ireland  
*Richard S.J. Tol* |
|      | 363    | The Effects of the Internationalisation of Firms on Innovation and Productivity  
*Iulia Siedschlag, Xiaoheng Zhang* and Brian Cahill |
|      | 362    | Too much of a good thing? Gender, ‘Concerted cultivation’ and unequal achievement in primary education  
*Selina McCoy, Delma Byrne, Joanne Banks* |
|      | 361    | Timing and Determinants of Local Residential Broadband Adoption: Evidence from Ireland  
*Seán Lyons* |
|      | 360    | Determinants of Vegetarianism and Partial Vegetarianism in the United Kingdom  
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|      | 359    | From Data to Policy Analysis: Tax-Benefit Modelling using SILC 2008  
*Tim Callan, Claire Keane, John R. Walsh and Marguerita Lane* |
|      | 358    | Towards a Better and Sustainable Health Care System – Resource Allocation and Financing Issues for Ireland  
*Frances Ruane* |
|      | 357    | An Estimate of the Value of Lost Load for Ireland  
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Stefanie A. Haller and Liam Murphy

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Olivier Bargain, Libertad González, Claire Keane and Berkay Özcan

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Philip J. O’Connell, Seamus McGuinness, Elish Kelly

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Tim Callan, Brian Nolan (UCD) and John Walsh

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Gregory Swinand, Conor O’Toole and Seán Lyons

The Impact of Climate Policy on Private Car Ownership in
Ireland
Hugh Hennessy and Richard S.J. Tol

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Eimear Leahy, Seán Lyons and Richard S.J. Tol

340 An Estimate of the Number of Vegetarians in the World
Eimear Leahy, Seán Lyons and Richard S.J. Tol

339 International Migration in Ireland, 2009
Philip J O’Connell and Corona Joyce

338 The Euro Through the Looking-Glass: Perceived Inflation Following the 2002 Currency Changeover
Pete Lunn and David Duffy

337 Returning to the Question of a Wage Premium for Returning Migrants
Alan Barrett and Jean Goggin

2009

336 What Determines the Location Choice of Multinational Firms in the ICT Sector?
Iulia Siedschlag, Xiaoheng Zhang, Donal Smith

335 Cost-benefit analysis of the introduction of weight-based charges for domestic waste – West Cork’s experience
Sue Scott and Dorothy Watson

334 The Likely Economic Impact of Increasing Investment in Wind on the Island of Ireland
Conor Devitt, Séan Diffney, John Fitz Gerald, Seán Lyons and Laura Malaguzzi Valeri

333 Estimating Historical Landfill Quantities to Predict Methane Emissions
Seán Lyons, Liam Murphy and Richard S.J. Tol

332 International Climate Policy and Regional Welfare Weights
Daiju Narita, Richard S. J. Tol, and David Anthoff

331 A Hedonic Analysis of the Value of Parks and Green Spaces in the Dublin Area
Karen Mayor, Seán Lyons, David Duffy and Richard S.J. Tol

330 Measuring International Technology Spillovers and Progress Towards the European Research Area
Iulia Siedschlag
Climate Policy and Corporate Behaviour
Nicola Commins, Seán Lyons, Marc Schiffbauer, and Richard S.J. Tol

The Association Between Income Inequality and Mental Health: Social Cohesion or Social Infrastructure
Richard Layte and Bertrand Maître

A Computational Theory of Exchange: Willingness to pay, willingness to accept and the endowment effect
Pete Lunn and Mary Lunn

Fiscal Policy for Recovery
John Fitz Gerald

The EU 20/20/2020 Targets: An Overview of the EMF22 Assessment
Christoph Böhringer, Thomas F. Rutherford, and Richard S.J. Tol

Counting Only the Hits? The Risk of Underestimating the Costs of Stringent Climate Policy
Massimo Tavoni, Richard S.J. Tol

International Cooperation on Climate Change Adaptation from an Economic Perspective
Kelly C. de Bruin, Rob B. Dellink and Richard S.J. Tol

What Role for Property Taxes in Ireland?
T. Callan, C. Keane and J.R. Walsh

The Public-Private Sector Pay Gap in Ireland: What Lies Beneath?
Elish Kelly, Seamus McGuinness, Philip O’Connell

A Code of Practice for Grocery Goods Undertakings and An Ombudsman: How to Do a Lot of Harm by Trying to Do a Little Good
Paul K Gorecki

Negative Equity in the Irish Housing Market
David Duffy

Estimating the Impact of Immigration on Wages in Ireland
Alan Barrett, Adele Bergin and Elish Kelly

Assessing the Impact of Wage Bargaining and Worker Preferences on the Gender Pay Gap in Ireland Using the
National Employment Survey 2003
Seamus McGuinness, Elish Kelly, Philip O'Connell, Tim Callan

Mismatch in the Graduate Labour Market Among Immigrants and Second-Generation Ethnic Minority Groups
Delma Byrne and Seamus McGuinness

Managing Housing Bubbles in Regional Economies under EMU: Ireland and Spain
Thomas Conefrey and John Fitz Gerald

Job Mismatches and Labour Market Outcomes
Kostas Mavromaras, Seamus McGuinness, Nigel O'Leary, Peter Sloane and Yin King Fok

Immigrants and Employer-provided Training
Alan Barrett, Séamus McGuinness, Martin O'Brien and Philip O'Connell

Did the Celtic Tiger Decrease Socio-Economic Differentials in Perinatal Mortality in Ireland?
Richard Layte and Barbara Clyne

Exploring International Differences in Rates of Return to Education: Evidence from EU SILC
Maria A. Davia, Seamus McGuinness and Philip, J. O'Connell

Car Ownership and Mode of Transport to Work in Ireland
Nicola Commins and Anne Nolan

Recent Trends in the Caesarean Section Rate in Ireland 1999-2006
Aoife Brick and Richard Layte

Price Inflation and Income Distribution
Anne Jennings, Seán Lyons and Richard S.J. Tol

Overskilling Dynamics and Education Pathways
Kostas Mavromaras, Seamus McGuinness, Yin King Fok

What Determines the Attractiveness of the European Union to the Location of R&D Multinational Firms?
Iulia Siedschlag, Donal Smith, Camelia Turcu, Xiaoheng Zhang

Do Foreign Mergers and Acquisitions Boost Firm Productivity?
Marc Schiffbauer, Iulia Siedschlag, Frances Ruane

Inclusion or Diversion in Higher Education in the Republic of Ireland?
<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare Regime and Social Class Variation in Poverty and Economic</td>
<td>Delma Byrne</td>
</tr>
<tr>
<td>Vulnerability in Europe: An Analysis of EU-SILC</td>
<td></td>
</tr>
<tr>
<td>Christopher T. Whelan and Bertrand Maître</td>
<td></td>
</tr>
<tr>
<td>Understanding the Socio-Economic Distribution and Consequences of</td>
<td></td>
</tr>
<tr>
<td>Patterns of Multiple Deprivation: An Application of Self-Organising</td>
<td></td>
</tr>
<tr>
<td>Maps</td>
<td>Christopher T. Whelan, Mario Lucchini, Maurizio Pisati and Bertrand</td>
</tr>
<tr>
<td>Maître</td>
<td></td>
</tr>
<tr>
<td>Estimating the Impact of Metro North</td>
<td>Edgar Morgenroth</td>
</tr>
<tr>
<td>Explaining Structural Change in Cardiovascular Mortality in Ireland</td>
<td>Richard Layte, Sinead O’Hara and Kathleen Bennett</td>
</tr>
<tr>
<td>1995-2005: A Time Series Analysis</td>
<td></td>
</tr>
<tr>
<td>Mechanism More Effectively</td>
<td></td>
</tr>
<tr>
<td>Irish Public Capital Spending in a Recession</td>
<td>Edgar Morgenroth</td>
</tr>
<tr>
<td>Exporting and Ownership Contributions to Irish Manufacturing Productivity Growth</td>
<td>Anne Marie Gleeson, Frances Ruane</td>
</tr>
<tr>
<td>Eligibility for Free Primary Care and Avoidable Hospitalisations in</td>
<td>Anne Nolan</td>
</tr>
<tr>
<td>Ireland</td>
<td></td>
</tr>
<tr>
<td>Managing Household Waste in Ireland: Behavioural Parameters and</td>
<td>John Curtis, Seán Lyons and Abigail O’Callaghan-Platt</td>
</tr>
<tr>
<td>Policy Options</td>
<td></td>
</tr>
<tr>
<td>Labour Market Mismatch Among UK Graduates; An Analysis Using REFLEX</td>
<td>Seamus McGuinness and Peter J. Sloane</td>
</tr>
<tr>
<td>Data</td>
<td></td>
</tr>
<tr>
<td>Towards Regional Environmental Accounts for Ireland</td>
<td>Richard S.J. Tol, Nicola Commins, Niamh Crilly, Sean Lyons and Edgar</td>
</tr>
<tr>
<td>Morgenroth</td>
<td></td>
</tr>
<tr>
<td>EU Climate Change Policy 2013-2020: Thoughts on Property Rights and</td>
<td></td>
</tr>
<tr>
<td>Market Choices</td>
<td></td>
</tr>
</tbody>
</table>
Paul K. Gorecki, Sean Lyons and Richard S.J. Tol

291 Measuring House Price Change  
*David Duffy*

290 Intra-and Extra-Union Flexibility in Meeting the European Union's Emission Reduction Targets  
*Richard S.J. Tol*

289 The Determinants and Effects of Training at Work: Bringing the Workplace Back In  
*Philip J. O'Connell* and *Delma Byrne*

288 Climate Feedbacks on the Terrestrial Biosphere and the Economics of Climate Policy: An Application of *FUND*  
*Richard S.J. Tol*

287 The Behaviour of the Irish Economy: Insights from the HERMES macro-economic model  
*Adele Bergin, Thomas Conefrey, John FitzGerald* and *Ide Kearney*

286 Mapping Patterns of Multiple Deprivation Using Self-Organising Maps: An Application to EU-SILC Data for Ireland  
*Maurizio Pisati, Christopher T. Whelan*, Mario Lucchini and *Bertrand Maître*

285 The Feasibility of Low Concentration Targets: An Application of *FUND*  
*Richard S.J. Tol*

284 Policy Options to Reduce Ireland’s GHG Emissions Instrument choice: the pros and cons of alternative policy instruments  
*Thomas Legge* and *Sue Scott*

283 Accounting for Taste: An Examination of Socioeconomic Gradients in Attendance at Arts Events  
*Pete Lunn* and *Elish Kelly*

282 The Economic Impact of Ocean Acidification on Coral Reefs  
*Luke M. Brander, Katrin Rehdanz, Richard S.J. Tol*, and *Pieter J.H. van Beukering*

281 Assessing the impact of biodiversity on tourism flows: A model for tourist behaviour and its policy implications  
*Giulia Macagno, Maria Loureiro, Paulo A.L.D. Nunes* and *Richard
Advertising to boost energy efficiency: the Power of One campaign and natural gas consumption
Seán Diffney, Seán Lyons and Laura Malaguzzi Valeri

International Transmission of Business Cycles Between Ireland and its Trading Partners
Jean Goggin and Iulia Siedschlag

Optimal Global Dynamic Carbon Taxation
David Anthoff

Energy Use and Appliance Ownership in Ireland
Eimear Leahy and Seán Lyons

Discounting for Climate Change
David Anthoff, Richard S.J. Tol and Gary W. Yohe

Projecting the Future Numbers of Migrant Workers in the Health and Social Care Sectors in Ireland
Alan Barrett and Anna Rust

Economic Costs of Extratropical Storms under Climate Change: An application of FUND
Daiju Narita, Richard S.J. Tol, David Anthoff

The Macro-Economic Impact of Changing the Rate of Corporation Tax
Thomas Conefrey and John D. Fitz Gerald

The Games We Used to Play
An Application of Survival Analysis to the Sporting Life-course
Pete Lunn

Exploring the Economic Geography of Ireland
Edgar Morgenroth

Benchmarking, Social Partnership and Higher Remuneration: Wage Settling Institutions and the Public-Private Sector Wage Gap in Ireland
Elish Kelly, Seamus McGuinness, Philip O’Connell

A Dynamic Analysis of Household Car Ownership in Ireland
Anne Nolan

The Determinants of Mode of Transport to Work in the Greater
Dublin Area

Nicola Commins and Anne Nolan

267 Resonances from Economic Development for Current Economic Policymaking
Frances Ruane

266 The Impact of Wage Bargaining Regime on Firm-Level Competitiveness and Wage Inequality: The Case of Ireland
Seamus McGuinness, Elish Kelly and Philip O’Connell

265 Poverty in Ireland in Comparative European Perspective
Christopher T. Whelan and Bertrand Maître

264 A Hedonic Analysis of the Value of Rail Transport in the Greater Dublin Area
Karen Mayor, Seán Lyons, David Duffy and Richard S.J. Tol

263 Comparing Poverty Indicators in an Enlarged EU
Christopher T. Whelan and Bertrand Maître

262 Fuel Poverty in Ireland: Extent, Affected Groups and Policy Issues
Sue Scott, Seán Lyons, Claire Keane, Donal McCarthy and Richard S.J. Tol

261 The Misperception of Inflation by Irish Consumers
David Duffy and Pete Lunn

260 The Direct Impact of Climate Change on Regional Labour Productivity

259 Damage Costs of Climate Change through Intensification of Tropical Cyclone Activities: An Application of FUND
Daiju Narita, Richard S. J. Tol and David Anthoff

258 Are Over-educated People Insiders or Outsiders? A Case of Job Search Methods and Over-education in UK
Aleksander Kucel, Delma Byrne

257 Metrics for Aggregating the Climate Effect of Different Emissions: A Unifying Framework
Richard S.J. Tol, Terje K. Berntsen, Brian C. O’Neill, Jan S. Fuglestvedt, Keith P. Shine, Yves Balkansi and Laszlo Makra
Intra-Union Flexibility of Non-ETS Emission Reduction Obligations in the European Union
Richard S.J. Tol

The Economic Impact of Climate Change
Richard S.J. Tol

Measuring International Inequity Aversion
Richard S.J. Tol

Using a Census to Assess the Reliability of a National Household Survey for Migration Research: The Case of Ireland
Alan Barrett and Elish Kelly

Risk Aversion, Time Preference, and the Social Cost of Carbon
David Anthoff, Richard S.J. Tol and Gary W. Yohe

The Impact of a Carbon Tax on Economic Growth and Carbon Dioxide Emissions in Ireland
Thomas Conefrey, John D. Fitz Gerald, Laura Malaguzzi Valeri and Richard S.J. Tol

The Distributional Implications of a Carbon Tax in Ireland
Tim Callan, Sean Lyons, Susan Scott, Richard S.J. Tol and Stefano Verde

Measuring Material Deprivation in the Enlarged EU
Christopher T. Whelan, Brian Nolan and Bertrand Maître

Marginal Abatement Costs on Carbon-Dioxide Emissions: A Meta-Analysis

Incorporating GHG Emission Costs in the Economic Appraisal of Projects Supported by State Development Agencies
Richard S.J. Tol and Seán Lyons

A Carton Tax for Ireland
Richard S.J. Tol, Tim Callan, Thomas Conefrey, John D. Fitz Gerald, Seán Lyons, Laura Malaguzzi Valeri and Susan Scott

Non-cash Benefits and the Distribution of Economic Welfare
Tim Callan and Claire Keane

Scenarios of Carbon Dioxide Emissions from Aviation
Karen Mayor and Richard S.J. Tol

The Effect of the Euro on Export Patterns: Empirical Evidence
from Industry Data
Gavin Murphy and Iulia Siedschlag

242 The Economic Returns to Field of Study and Competencies Among Higher Education Graduates in Ireland
Elish Kelly, Philip O’Connell and Emer Smyth

241 European Climate Policy and Aviation Emissions
Karen Mayor and Richard S.J. Tol

240 Aviation and the Environment in the Context of the EU-US Open Skies Agreement
Karen Mayor and Richard S.J. Tol

239 Yuppie Kvetch? Work-life Conflict and Social Class in Western Europe
Frances McGinnity and Emma Calvert

Alan Barrett and Yvonne McCarthy

237 How Local is Hospital Treatment? An Exploratory Analysis of Public/Private Variation in Location of Treatment in Irish Acute Public Hospitals
Jacqueline O’Reilly and Miriam M. Wiley

236 The Immigrant Earnings Disadvantage Across the Earnings and Skills Distributions: The Case of Immigrants from the EU’s New Member States in Ireland
Alan Barrett, Seamus McGuinness and Martin O’Brien

235 Europeanisation of Inequality and European Reference Groups
Christopher T. Whelan and Bertrand Maître

234 Managing Capital Flows: Experiences from Central and Eastern Europe
Jürgen von Hagen and Iulia Siedschlag

Charlie Karlsson, Gunther Maier, Michaela Trippl, Iulia Siedschlag, Robert Owen and Gavin Murphy

232 Welfare and Competition Effects of Electricity Interconnection between Great Britain and Ireland
Laura Malaguzzi Valeri
223 Is FDI into China Crowding Out the FDI into the European Union?
Laura Resmini and Iulia Siedschlag

230 Estimating the Economic Cost of Disability in Ireland
John Cullinan, Brenda Gannon and Seán Lyons

229 Controlling the Cost of Controlling the Climate: The Irish Government's Climate Change Strategy
Colm McCarthy, Sue Scott

228 The Impact of Climate Change on the Balanced-Growth-Equivalent: An Application of FUND
David Anthoff, Richard S.J. Tol

227 Changing Returns to Education During a Boom? The Case of Ireland
Seamus McGuinness, Frances McGinnity, Philip O’Connell

226 ‘New’ and ‘Old’ Social Risks: Life Cycle and Social Class Perspectives on Social Exclusion in Ireland
Christopher T. Whelan and Bertrand Maître

225 The Climate Preferences of Irish Tourists by Purpose of Travel
Seán Lyons, Karen Mayor and Richard S.J. Tol

224 A Hirsch Measure for the Quality of Research Supervision, and an Illustration with Trade Economists
Frances P. Ruane and Richard S.J. Tol

223 Environmental Accounts for the Republic of Ireland: 1990-2005
Seán Lyons, Karen Mayor and Richard S.J. Tol

2007 222 Assessing Vulnerability of Selected Sectors under Environmental Tax Reform: The issue of pricing power
J. Fitz Gerald, M. Keeney and S. Scott

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
The Public/Private Mix in Irish Acute Public Hospitals: Trends and Implications
   Jacqueline O’Reilly and Miriam M. Wiley

Regret About the Timing of First Sexual Intercourse: The Role of Age and Context
   Richard Layte, Hannah McGee

Determinants of Water Connection Type and Ownership of Water-Using Appliances in Ireland
   Joe O'Doherty, Seán Lyons and Richard S.J. Tol

Unemployment – Stage or Stigma?
   Being Unemployed During an Economic Boom
   Emer Smyth

The Value of Lost Load
   Richard S.J. Tol

Adolescents’ Educational Attainment and School Experiences in Contemporary Ireland
   Merike Darmody, Selina McCoy, Emer Smyth

Acting Up or Opting Out? Truancy in Irish Secondary Schools
   Merike Darmody, Emer Smyth and Selina McCoy

Where do MNEs Expand Production: Location Choices of the Pharmaceutical Industry in Europe after 1992
   Frances P. Ruane, Xiaoheng Zhang

Holiday Destinations: Understanding the Travel Choices of Irish Tourists
   Seán Lyons, Karen Mayor and Richard S.J. Tol

The Effectiveness of Competition Policy and the Price-Cost Margin: Evidence from Panel Data
   Patrick McClooughan, Seán Lyons and William Batt

Tax Structure and Female Labour Market Participation: Evidence from Ireland
   Tim Callan, A. Van Soest, J.R. Walsh