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A new economics approach to modelling policies for climate change mitigation

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Abstract
This paper explores a Post Keynesian, "new economics" approach to climate policy, assessing the opportunities for investment in accelerated decarbonisation of the global economy to 2020 following the Great Recession of 2008-2009. The risks associated with business-as-usual growth in greenhouse gas (GHG) concentrations in the atmosphere suggest that avoiding dangerous climate change will require that the world's energy-economy system is transformed through wholesale switching to low-carbon technologies and lifestyles. Governments have agreed a target to hold the increase in temperatures above pre-industrial levels to at most 2ºC and have offered reductions by 2020 in GHG emissions or the carbon-intensity of GDP. The effects of policies proposed to achieve pathways to 2020 towards this target are assessed using E3MG, an Energy-Environment-Economy (E3) Model at the Global level. E3MG is an annual simulation econometric model, estimated for 20 world regions 1972-2006 adopting a new economics approach. Additional low-GHG investment of some 0.7% of GDP, with carbon pricing and other policies, is sufficient to achieve a pathway consistent with a medium chance of achieving the long-term target. Employment is some 1.5% above reference levels by 2020 and public finances are almost unaffected.

***Keywords**:* climate change mitigation; green new deal; energy-environment-economy (E3) modelling; post-2012 policies; World Energy Outlook

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1. A New Economics Approach to Climate Change Mitigation

1.1 Introduction

This paper explores the effects on the global economy of climate policies designed to achieve interim targets for GHG mitigation implied by the long-term target agreed in the Copenhagen Accord, 2009, and confirmed in the Cancun Agreements, 2010. The approach to policy analysis is Post Keynesian in that the fiscal stimulus from investment to mitigate climate change is allowed to reduce unemployment in both the short and long runs. The stimulus packages implemented by governments in 2009 and 2010 following the onset of the Great Recession are the starting points for a wider and longer programme of investment to decarbonise the global economy. We use a global "new economics", Post Keynesian model with estimated energy demand equations to suggest how policy portfolios and strategies can be developed to generate "green growth" while simultaneously reducing greenhouse gas emissions at the rates deemed necessary to achieve the climate targets. The focus of the paper is on the initial phase of the decarbonisation of the global economy, i.e. the effects of long-term policies on outcomes to 2020. One reason is that 2020 has become important for such policies, as the target year chosen for the reductions in GHG emissions and carbon intensity of economies in the Cancun Agreement. Another reason is that the period is one of recovery after the Great Recession. The need for fiscal stimulus gives the opportunity to re-orientate economies towards green growth at low cost or even benefit.

1.2 The new economics approach

In the literature, much of the macroeconomic analysis of policies for climate change mitigation (IPCC, 2007) has been undertaken with traditional approaches to understanding the economy. Typically long-run growth has been assumed to be determined from the supply-side with economies in full-employment equilibrium. The growth rates then depend on those of labour supply and exogenous technological change. There no allowance for demand-side effects or the possibility of unemployment being lower in the long term. The models have assumed representative agents, with no room for a variety of responses.

In this paper we approach the economics of climate change mitigation using the new economics outlined by Barker (2008, 2011) and represented in E3MG, an Energy-Environment-Economy Model at the Global level (Barker et al., 2006; Barker and Scrieciu, 2010). A brief summary of the approach is given here. In contrast with traditional models, economic growth is demand-driven and supply-constrained, with no assumption of the economy being in full-employment equilibrium. The world economy is treated as an open system of interacting economies with different levels of unemployment and financial imbalances. In order to implement the institutional aspect of new economics, namely that economic activity is highly specific to location and timing, the model is disaggregated into 20 world regions and 41 industrial sectors in each region. Although there are regional macroeconomic variables derived by aggregation, such as GDP, and global variables, such as the world oil price, many economic activities, such as output, investment, employment, exports and imports, and associated prices, are treated at the industrial or product level. The assumption is that each industry has its own institutional rules and procedures. The model is further disaggregated in its treatment of consumers' and government expenditures, in energy demand and supply, and in emissions of pollutants into the atmosphere.

A crucial Post Keynesian feature of the model is that it represents observed behavior. It is a simulation econometric model based on annual data 1970-2006 and input-output data for the year 2000. The economic data is organized around the Social Accounting Matrix with supply-demand balances for 20 regions and 41 products. The model includes 22 sets of stochastic equations estimated with short- and long-term components by instrumental variables for aggregate consumption, consumers' expenditure shares, investment, employment, exports, imports, prices and wage rates, energy demands, fuel shares, and labour participation rates. Population, exchange rates and interest rates, government spending, tax and other fiscal policies, and the availability of natural resources are taken as exogenous.

In this approach, fiscal policy is paramount in managing the economy, with monetary policy responsible for maintaining financial stability, interest rates and exchange rates. In the modelling, industrial output is determined as the sum of intermediate demands from other industries and the final demands of households, government, investment and net international trade. Employment is derived from output, allowing for varying returns to scale across industries and over time. The estimated equations show that in the long-run, employment rises less than output in most industries, i.e. there are economies of scale and specialization. Employment can increase through changes in industrial structure with economic growth, so that employment–intensive sectors such as health and education increase relative to manufacturing or through fiscal policy changing the level or structure of demand over time. Unemployment is the difference between employment and participation in the working population. Participation in turn depends on the level of unemployment (the "discouraged worker effect" with higher unemployment).

2. Climate Change Mitigation after the Great Recession

2.1 The financial crisis and the climate crisis: causes and consequences

Both the financial and climate crises are instances of large-scale market failures associated with systemic risks. The market failure of the financial system is when the banks fail to take account of the risk that house and other asset prices might fall, and hence undermine their solvency. The market failure associated with climate change is the use of the atmosphere as free waste disposal for greenhouse gas (GHG) emissions. The emissions from burning of fossil fuels and biomass in market-induced deforestation increase the stock of GHGs in the atmosphere leading to global warming, and this in turn gives rise to damaging climate change. Both failures are highly non-linear systems failures leading to extreme events in the economy, and both threaten the world's economies with collapse in the short or long run. The recognised solutions to both market failures are combinations of effective regulation and long-term pricing of risk, in the forms of international standards for banks in creating risky assets, and an effective, efficient and equitable strategy to reduce greenhouse gas emissions.

2.2 Proposals for a "Green New Deal"

As the financial crisis of 2008 progressed and governments responded by adopting Keynesian reflationary policies to prevent economic collapse, a literature developed in proposing a "Green New Deal" for the recovery packages. The first proposal was by a group largely consisting of UK environmental policy activists and published by the New Economics Foundation (May, 2008). The group examined the emerging financial, energy and climate crises and proposed a coherent set of policies, aimed at UK policy makers, to solve them. A less ambitious set of proposals was aimed at US policymakers by Polin et al. (2008). As the financial crisis deepened with the bankruptcy of the Lehman bank in September 2008 and the subsequent fall in world trade and output, the need for coordinated global action became apparent. Proposals for a green stimulus package were formulated in the period leading to the London G20 summit in April 2009 (Barbier, 2009; UNEP, 2009a; Edenhofer and Stern, 2009; Bowen at al., 2009). Barbier's report (2009) was commissioned by the UN Environment Programme (UNEP) and called for 1% of GDP in the stimulus packages to be used for green investments in low-carbon electricity supply, energy efficiency, transport and water infrastructure. The potential for an alternative greener economy to reduce the effects of high oil prices on oil-importing economies was explored by Pollitt and Junankar (2009). The UNEP has followed up the first proposal in a later report (2009b) and action involving green investments of 2% of global GDP (UNEP, 2011), and Barbier went on to consolidate his work into a review of progress (2010a) and a book (2010b).

2.3 Policies to restore the global economy to sustainable growth

Many governments recognised the benefits of combining economic recovery with improvements to the environment. The overall green stimulus announced in 2009 was some $436bn out of $2796bn (Edenhofer and Stern, 2009), but these totals are of direct government spending spread over two or more years (2009-2010 for China, over ten years for the US) so the annual amounts will be half or less. They also cover a wide range of environmental policies as well as climate change mitigation. Much of the spending is on energy efficiency improvements, but without a carbon price there may be substantial rebound effects, maybe as high as 50% (Barker et al., 2009). The rebound comes as the users of energy take some of the benefits of the increased efficiency in the form of more energy services, such as more comfort or more travel, so offsetting the hoped-for reduction in energy use and hence greenhouse gas emissions. This rebound effect seems likely to be stronger in developing countries, where consumption of energy in the home is well below saturation levels.

The scale of the green spending compares with the target of 1% of GDP for the low-carbon economy and sustainable transport called for by the UNEP report on the Global Green New Deal (Barbier, 2009). This translates to some $656bn pa globally, $138bn for the US, $144bn for the EU and $71bn for China, using 2007 estimates of global GDP. The estimated spend by China of $110bn a year 2009-2010 is well above the 1%, but the other estimates, at least for the major economies, fall far short of the 1% target.

2.4 Economic recovery and climate change mitigation following the Great Recession

The collapse of the global investment banks led to reductions in lending and hence industrial output, trade, personal incomes and household expenditures, and then in turn to reductions in energy use and in greenhouse gas emissions. However, the global levels of CO_2 emissions from energy use were almost unchanged from 2008 to 2009 (US EIA, 2010) because the reductions in the USA and other economies leading the recession were offset by increases in China and other developing countries. China had already become the largest country emitter of CO_2 in 2007. The Great Recession led to USA emissions falling by 7.0% in 2009, but the recovery led to China's emissions rising by 13.3% in 2009 (US EIA, 2010).

The long-term effect of the crisis has been to accelerate the shift of production and emissions to developing countries, especially China, so that it has become even more obvious that policies for decarbonisation must be adopted world-wide for climate change targets to be achieved. There is recognition of the importance for China of reducing polluting emissions in the official announcements of the Twelfth 5-year Plan 2010-2015 adopted in 2011, which aims to raise non-fossil sources to 20% of total energy by 2015.

The conclusion on prospects under current policies is that first decline and then possibly slower growth in the world economy will lead to lower greenhouse gas emissions than previously expected, but these will be offset by a shift towards more use of coal in developing countries. The plans for greener growth, especially in China, may reduce prospective CO_2 emissions, but there is a risk of rebound effects if carbon prices are not high enough. The overall picture is that greenhouse gas emissions have resumed an upward trend after the recession and that, without further substantial action to promote a long-term green recovery, the targets of the Copenhagen Accord of 2009 and the Cancun Agreement of December 2010 will not be reached. Countries have made commitments to reduce by 2020 their GHG emissions or the CO_2-intensity of their economies, but there remains a potential "emissions gap" between the reduction required for the 2ºC target and the likely outcome of these commitments.

2.4 Pathways to 2020 to reach climate targets

The United Nations Environment Programme has compiled an expert analysis of this emissions gap (UNEP, 2010). It is based on recent literature using Integrated Assessment Models presenting GHG pathways to achieve the 2ºC target by 2100. Some 27 pathways are covered, divided into those which give a medium chance of achieving the target (50 to 66%) and those that give a likely chance (better than 66%). Each of these sets of pathways is further divided into those that do and do not assume substantial adoption of technologies that remove CO_2 from the air so that net emissions from energy use and industrial processes are negative after 2060. The main such technology is combustion for electricity generation with biomass and with capture and storage of the resulting CO_2 emissions. All imply a peak of emissions between 2010 and 2020. Table 1 summarises the target levels for global GHG emissions by 2020.

Table 1: Target GHG emissions levels for 2020 from Integrated Assessment Models

2° C pathways	Number of Pathways	2020 total emission levels ($GtCO_2$-eq)	
		Median	20th-80th percentile range
"Likely" chance (greater than 66 per cent) of staying below 2° C during twenty-first century			
Without negative CO_2 emissions from energy and industry	2	31	28 to 34
With negative CO_2 emissions from energy and industry	7	44	44 to 44
"Medium" chance (50 to 66 per cent) of staying below 2° C during twenty-first century			
Without negative CO_2 emissions from energy and industry	9	44	42 to 45
With negative CO_2 emissions from energy and industry	9	45	42 to 46

Source: UNEP, 2010, p. 29

These global emissions are compared with the projections for 2020 estimated without including the agreements reached in Copenhagen and with different combinations of assumptions about the conditionality of the pledges to reduce emissions and about how lenient or strict the unresolved accounting rules will be interpreted. The conditionality comes from countries promising to take more stringent action depending on the actions of other countries. The accounting rules relate to the treatment of surplus credits under the Kyoto Protocol and of emissions from land use and land use change (LULUC) in Annex 1 countries. (UNEP, 2010 pp. 33-36 gives more details). The outcomes under the different assumptions are summarised from nine studies in Table 2. It is clear from the median results that even the higher reductions from conditional pledges and strict rules implies an emission gap when compared to the emissions for 2020 for the 2ºC target from Table 1. The gap is some 4 to 8 $GtCO_2$-eq for the medium chance of achieving the target.

Table 2: Agreed GHG emissions levels for 2020 from Copenhagen Accord from nine studies

Pledges	Accounting rules	2020 total emission levels ($GtCO_2$-eq)	
		Median	20th-80th percentile range
None (business as usual)	none	55.5	54.3 to 59.9
Unconditional	lenient	53.0	51.8 to 57.1
Unconditional	strict	51.9	50.3 to 55.1
Conditional	lenient	51.4	48.8 to 53.0
Conditional	strict	49.0	46.7 to 50.9

Source: UNEP, 2010, p. 29.

The UNEP report does not assess the policies and measures that may be required to close the emissions gap. This paper uses a modelling approach, described in the next section, to assess the policies and measures proposed by the International Energy Agency in its World Energy Outlook 2010 (IEA WEO, 2010) as an interpretation of what is needed to put world GHG emissions by 2020 on a pathway to achieve the long-term climate targets.

3. Modelling the Effects of Climate Policies

The effects of climate policies are investigated here using E3MG, a sectoral dynamic macroeconomic model of the global economy, which has been designed to assess options for climate and energy policies and to allow for energy-environment-economy (E3) interactions (Barker *et al*., 2006; Barker *et al.*, 2008)[1]. The model is organised around production sectors, which enables a more accurate representation of the effects of policies than is common in most macroeconomic modelling approaches. The model addresses the issues of energy security and climate stabilisation both in the medium and long terms, with particular emphasis on dynamics, uncertainty and the design and use of economic instruments, such as emission allowance trading schemes. E3MG is a non-equilibrium model with an open structure such that labour, foreign exchange and public financial markets are not necessarily closed. It is very disaggregated, with 20 world regions, 41 production sectors, 12 energy carriers, 19 energy users, 28 energy technologies and 14 atmospheric emissions, with comparable detail for the rest of the real economy. The model represents a novel long-term economic modelling approach in the treatment of technological change, since it is based on cross-section and time-series data analysis of the global system 1973-2006 (in the version used for this paper) using formal econometric techniques, and thus provides a different perspective on the costs of climate stabilisation compared with traditional equilibrium models.

[1] This section gives a very brief description of the model. Further details are in http://sites.google.com/site/4cmrhome/home/our-research/e3mg and http://www.e3mgmodel.com

The model is based upon a Post Keynesian economic view of the long-run. In other words, in modelling long-run economic growth and technological change we have adopted the "history" approach of cumulative causation and demand-led growth (Kaldor, 1957, 1972, 1985; Setterfield, 2002), focusing on gross investment (Scott, 1989) and trade, and incorporating technological progress in gross investment enhanced by R&D expenditures. Other Post Keynesian features of the model (see Holt, 2007, for a discussion of such features) include: varying returns to scale (that are derived from estimation), non-equilibrium, not assuming full employment, varying degrees of competition, and the feature that industries act as social groups and not as a group of individual firms (i.e. no optimisation is assumed but bounded rationality is implied). The grouping of countries and regions has been based on political criteria. At the global level, accounting conventions are imposed so that the expenditure components of GDP add up to total GDP and total exports equal total imports at a sectoral level allowing for imbalances in the data.

The separate long-run relationships in the model are to be seen as based on uncertain averages, restricted so that the solution is stable and that demand is unchanged or reduced in response to an increase in relative prices. Consumers' expenditure, the main driver of final demand in each region, is affected by population, income and the value of dwellings. Investment and employment are derived from industrial output, prices and wage rates relative to the prices of what they produce, real interest rates and technological progress. Exports and imports depend on activity in their markets, relative prices and technological progress. Industrial intermediate demand is derived from input-output relationships. Energy demand is derived from industrial output, consumers' income and trade, as well as relative prices and technological progress. The fuels supplying the energy are estimated by fuel share equations and the mix of fuels demanded is used to change the input-output coefficients and consumer shares for fuel use. Technological progress is measured by accumulated investment enhanced by R&D spending. Prices and wage rates are dependent on unit labour and other input costs, tax, subsidy and exchange rates and exchange rates and utilization of capacity.

For this paper, we are focussing on an investment programme for decarbonisation over the years to 2020. A sizeable component of the investment is in low-carbon electricity capacity induced by a variety of policies, which we have made exogenous, relying on WEO 2010 for the estimates of the scale of energy saving and investment required. This capacity is imposed within the energy technology model incorporated in E3MG. The implementation of different policies through time, such as incentives, regulation, and revenue recycling allow low or non-carbon options to meet a larger part of global energy demand. The model includes 28 representative energy technologies, described by 21 technology characteristics, so the WEO estimates can be incorporated in some detail. The economy-wide effects are captured in E3MG through the interactions between the different sectors in the model, without assuming that resources are used at full economic efficiency.

An indication can be given of the properties of the model by calculating the fiscal multiplier, assuming that the extra investment spending is funded by governments. The global fiscal multiplier in E3MG is 1.6, i.e. GDP increases by 1.6 times the amount of the increase in investment, assuming no response in interest rates or exchange rates. This compares with the estimates presented by the IMF to the G20 London meeting of 0.5 to 1.8 for capital spending (Spilimbergo et al., 2009). Within this range, estimates from global models tend to be higher than those from national models, since at the global level all extra imports become other country's extra exports.

4. Description of Climate Mitigation Policies and Scenarios

4.1 Scenarios for decarbonisation and recovery and the Cancun Agreement

The modelling undertaken in this study required the specification of scenarios to reflect the set of policies for GHG mitigation. The reference scenario described below is intended to represent the outcome of adopting current policies, but without the extra efforts promised in the Cancun Agreement[2] to reduce GHG emissions by 2020. This scenario is mainly based on the IEA's current policies scenario (IEA WEO, 2010). This reference case is compared with two scenarios that include policies to increase investment and reduce GHG emissions. The 450 scenario includes the policies for reducing GHG emissions assumed in the IEA's 450 scenario (IEA WEO, 2010), which can be interpreted as the outcome of the Cancun Agreement at the high end of the range of commitments to reduce emissions. The Medium 2ºC scenario assumes a strengthening of these commitments to reach a level of emissions by 2020 with a medium (50 to 66%) chance of climate stabilisation as summarised in Table 3. The higher level of investment is designed to accelerate recovery towards full employment in those economies most affected by the Great Recession. In both policy scenarios, the CDM (Clean Development Mechanism) plays a role in transferring funding to developing countries for climate change mitigation.

Table 3: Some details of the E3MG scenarios

E3MG Scenario	**Reference**	**450**	**Medium 2ºC**
Description	Current policies	450ppmv CO_2-eq by 21**5**0	medium chance (50 to 66%) of reaching 2ºC target in 21st C
Source	WEO 2010	WEO 2010	this paper
Emissions Trading Scheme	EU only from 2005	EU from 2005 Other OECD from 2013	EU from 2005 Other OECD from 2013 China from 2013
Carbon price 2020 (2009$/t$CO_2$)	30	45	45
Annual additional investment into low-carbon technologies 2013-2020 (2009$bn pa)	n/a	395	474
Other policies	No new climate change mitigation and energy policies in addition to those formally adopted by mid-2010	Removal of fossil fuel subsidies in net-oil-importers by 2020 Clean Development Mechanism used to fund extra investment in least developed countries	Removal of fossil fuel subsidies in net-oil-importers by 2020 Clean Development Mechanism used to fund extra investment in least developed countries

The Reference Case is constructed to establish a projection of the global economy for the period 2013-2020 without the impact of additional decarbonisation policies. It is based on the assumptions of the current policies scenario of the IEA WEO (2010). E3MG provides a fully dynamic solution over the period, with results scaled to match those published in WEO.

The 450 and Medium 2ºC Policy Cases are alternative fully dynamic solutions, but including the sectoral effects on GHG emissions and energy use, year by year 2013-2020, of all the

[2] http://cancun.unfccc.int/

extra policies and measures introduced in the IEA's 450 scenario in WEO 2010, strengthened even further in the Medium 2ºC scenario to achieve a reduction in global GHG emissions of 15% below reference case by 2020. The difference between the Policy Cases and the Reference Case thus gives estimates of the impact of these policies on the global economy. The policy cases include carbon prices introduced through an emission trading scheme in OECD countries, extended to China in the Medium 2ºC scenario (see CCICED, 2009, for a discussion of policies for a low-carbon China). These schemes assume that all allowances are freely allocated to industry and that the extra costs are passed on as higher final product and electricity prices. One difference between the IEA's 450 scenario and the Medium 2ºC scenario of this study is that in our study the climate stabilisation target is reached in 2100 instead of 2150, which is the target year for the IEA's 450 scenario.

Within each scenario, the effects of the relevant policy measures are introduced into the model on an annual basis. The assumptions used in the modelling for carbon and oil prices are shown in Table 4. Note that we have assumed that OPEC restricts output to maintain the oil price when oil demand falls below that of the 450 scenario.

Table 4: Carbon and oil prices in the modelling scenarios

The Reference Case	2005	2010	2015	2020
EU ETS allowance price (2009\$/tCO_2)	27	22	26	30
OECD (excl. EU) ETS allowance price (2009\$/tCO_2)	0	0	0	0
Crude Oil (2009\$/bbl)	54	75	108	141
The 450 Policy Case	2005	2010	2015	2020
EU ETS allowance price (2009\$/tCO_2)	27	22	31	45
OECD (excl. EU) ETS allowance price (2009\$/tCO_2)	0	0	20	45
Crude Oil (2009\$/bbl)	54	75	101	116
The Medium 2ºC Policy Case	2005	2010	2015	2020
EU ETS allowance price (2009\$/tCO_2)	27	22	31	45
OECD (excl. EU) and China ETS allowance price (2009\$/tCO_2)	0	0	20	45
Crude Oil (2009\$/bbl)	54	75	101	116

Sources: IEA WEO, 2010 and E3MG.

4.2 Additional investment and regulation

The required additional annual investment for the post-2012 period 2013-2020 is presented for 2020 in Table 5, based on the IEA's 450 scenario (WEO, 2010, Figures 13.14 and 13.15, pp. 401). The investment is assumed for every year 2013-2020 and is related to the various policies and measures assumed for the different countries and regions. The investment is associated with additional regulation requiring gradually more stringent standards for lower carbon intensity in power generation, building and vehicles. The investment is assumed to be funded by increases in the price of electricity or the costs of buildings and vehicles. For the ***Medium 2ºC*** scenario the investment numbers are 20% higher at about \$500bn (2009) prices or 0.7% of world GDP in 2013. This additional investment is funded out of government borrowing.

Table 5: Projected annual global additional investment costs in 2020 for IEA WEO 2010 scenario 450 policies/measures used in this study as inputs to the modelling (billion 2009US$)

	Power Generation	Industry	Transport	Buildings	Biofuels	Total
United States	0.0	6.8	24.8	27.4	2.3	61.3
European Union	24.1	7.5	33.2	19.9	3.1	87.7
Japan	4.4	3.9	12.4	9.0	0.1	29.8
Other OECD+	2.9	4.8	14.8	12.4	1.0	36.0
Russia	0.0	0.8	4.6	2.6	0.1	8.1
China	18.9	9.4	24.6	23.0	0.3	76.2
India	2.4	1.7	10.3	4.6	0.1	19.0
Middle East	3.3	4.3	6.1	7.7	0.6	22.0
Other non-OECD	1.2	8.8	28.5	14.1	1.9	54.5
World	57.2	47.9	159.4	120.7	9.4	394.6

Source: IEA WEO, 2010

5. Results

5.1 The reference case

The growth rates for five key indicators in the reference case are shown in Table 6. As described in the previous section, these are produced using the E3MG model and are calibrated to be broadly consistent with the current policies case in the IEA's publication (IEA WEO, 2010), also taking into account the most recent data. The figures take into account the impact of the economic crisis.

Table 6: Average Annual World Growth of Key Macroeconomic Variables, Reference Case, %pa

	2000-2010	2010-2015	2015-2020
CO_2 Emissions	1.4	2.5	3.6
Final Energy Demand	1.9	1.3	1.8
GDP	2.4	3.6	2.9
Price index consumers' expenditure	3.3	2.6	2.4
Employment	1.0	1.1	1.1

Source: E3MG 2.4, 4CMR, Cambridge Econometrics, IEA.

Note: The projections are not forecasts. The significant figures given in this and later tables should not be taken to indicate reliability.

5.2 Results from the 450 and Medium 2ºC scenarios

Figure 1 shows the percentage difference from the reference case of global CO_2 emissions in the scenarios. The chart shows global energy-related CO_2 emissions to be 10% and 15% lower, for the 450 and Medium 2ºC scenarios respectively, compared to the reference case in 2020. Energy demand, measured as final energy consumption, falls by a similar amount. These reductions represent the combined effect of the large investment programmes and carbon pricing (including removal of existing subsidies) in the scenarios. On the other hand, the lower global energy prices encourage higher levels of consumption and emissions. The estimated effect is to reduce global GHG emissions from 52 $GtCO_2$-eq in the reference case to 47 $GtCO_2$-eq in the 450 scenario. Strengthened policies are required to reach 45 $GtCO_2$-eq to give a medium chance of achieving the 2ºC target over the 21st century (Table 1).

Figure 1: World CO2 Emissions, % difference from reference case

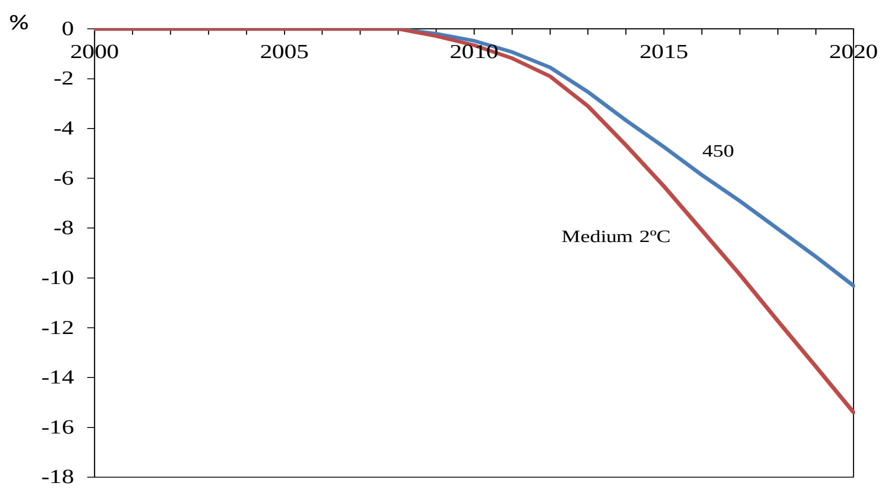
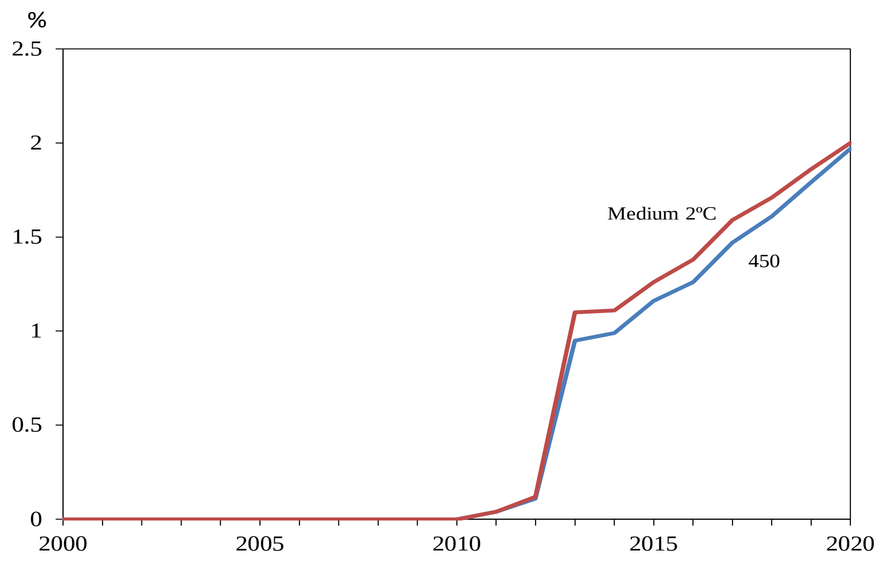


Figure 2 shows the impact of the measures on global GDP, as a percentage difference from reference case (i.e. comparing the results including climate policy to those based on current policy).

Figure 2: World GDP, % difference from reference case



The results from E3MG show that the economic impacts are generally small but positive, with the effects increasing over time. This is due to large increases in investment in new technologies, while the lower world oil prices in the policy scenario means that level of wealth flowing to oil-producing countries is reduced (as these countries have higher savings rates, reducing the transfer has a net positive effect on the global economy). These positive effects are enough to counter the costs associated with higher energy prices (e.g. through carbon pricing) and the costs associated with the investment.

Perhaps unexpectedly, overall price levels fall in both the 450 and Medium 2ºC scenarios. This is despite the very large investment costs and higher carbon prices, and is due to the lower world oil price assumptions (see Table 4) which outweigh the inflationary effects from such policies. In essence, production is moving away from tight oil supplies, reducing inflationary pressures.

Overall, there is a 2.5% reduction on average in world prices by 2020 compared with the reference case, although it is noted that electricity prices increase. Although these effects are quite small when spread across the whole period up to 2020, they could have a particular impact on low-income groups (which typically spend a larger share of income on energy for heating); this could be positive or negative and should be assessed further.

Employment is also expected to increase in the scenarios. There are two reasons for this:

- a general increase in economic activity creates additional jobs
- a shift in relative prices means that labour replaces energy as an input to production.

Unemployment is lower as a result.

In terms of the main components of GDP the scenarios represent a shift from household expenditure to long-term investment (the global trade balance is by definition unchanged, and we assume that government consumption does not change). Table 7 (see below) shows the impacts on GDP in three broad groupings; each group benefits overall, although the largest changes are seen in OECD+. The reason this group of countries benefits the most is that most of its economies do not rely on fossil fuel production for a substantial contribution to output.

Generally the sectors that benefit are those that produce investment goods (construction, engineering, metal goods), mainly at the expense of energy sectors (i.e. there is a shift from energy to capital as inputs to production). The pattern in employment is similar, although it should be noted that the investment sectors are much larger employers than the energy-extraction and processing industries.

The countries that benefit will therefore be the ones that specialise in producing investment goods while the ones that lose out will be those that export energy goods. For example, under current production patterns Germany is one of the main beneficiaries in the scenarios, while OPEC sees a net reduction in GDP due to lower global consumption of oil at lower prices.

In the Medium 2ºC scenario, the economic outcomes are not markedly different from those for the 450 scenario. In the Medium 2ºC scenario, GDP is slightly lower for China than in the 450 scenario as China faces higher domestic prices from introducing an emission trading scheme without recycling the possible revenues from auctioned allowances. This smaller impact can be seen in Table 7 in the GDP results for Other Major Economies, which includes China. GDP in other regions benefits slightly from higher investment in the Medium 2ºC scenario. Despite world GDP being unchanged, employment impacts are more positive in the Medium 2ºC scenario than the 450 scenario due to further increasing demand for biofuel-products, which are more labour intensive than the traditional fossil fuels extraction.

Table 7: CO_2 and macroeconomic variables as % difference from reference case in 2020

	Scenario	OECD+	Other major economies*	Other countries	World
CO_2 emissions (%)	450	- 10.2	- 8.7	- 14.7	- 10.3
CO_2 emissions (%)	Medium 2ºC	- 12.8	- 16.4	- 16.3	- 15.4
Final Energy Demand (%)	450	- 9.9	- 9.9	- 15.2	- 10.9
Final Energy Demand (%)	Medium 2ºC	- 10.8	- 21.4	- 16.7	- 16.2
GDP (%)	450	2.4	0.7	1.9	2.0
GDP (%)	Medium 2ºC	2.5	0.2	2.0	2.0
Price index consumers' expenditure (%)	450	- 2.9	- 1.5	- 1.6	- 2.6
Price index consumers' expenditure (%)	Medium 2ºC	- 2.9	- 1.3	- 1.2	- 2.5
Employment (%)	450	0.9	0.6	2.6	1.3
Employment (%)	Medium 2ºC	0.9	0.6	3.3	1.6

Note: OECD+: all OECD and non-OECD EU countries.
*Other major economies: Brazil, China, the Middle East, Russia but *not* South Africa. This is because South Africa falls under the 'rest of world' region within E3MG.

The effect of the climate policies on government financial balances is mixed, with several competing factors. Impacts that might reduce levels of government debt include:

- cutting of fuel subsidies
- a general increase in economic activity and employment, boosting tax receipts.

However, there are some impacts that may lead to an increase in government deficits:

- loss of revenue from fuel excise duties
- loss of revenue from energy extraction (e.g. in OPEC).

In the post-crisis world, much attention is being paid to government balances, with austerity plans now in place across much of Europe, and the Republicans in the US focusing on reducing the level of government debt. The complexity of national tax systems (and links to national oil companies) means it is difficult to produce a robust estimate of the impacts of the policies on government balances. Table 8 gives a rough estimate; the figures take into account the removal of subsidies and loss of earnings from excise duties, but also the indirect effects on the main direct taxes, social contributions and VAT revenues. It is assumed in the scenarios that government consumption and social transfers are unchanged in real terms beyond the reductions due to loss of earnings at state oil companies.

Overall, the results from the E3MG model suggest that enacting a broad set of climate policies could lead to a small improvement in government financial balances in the period up to 2020 (see Table 8) in the OECD regions, but not in the rest of the world. In the OECD, the measures would lead to quite substantial reductions in revenues from fuel excise duties (particularly in European countries where these have high rates) but this is outweighed by higher receipts of income and corporation taxes and VAT, related to the higher rates of economic growth. In developing countries there is also a positive effect via the removal of fuel subsidies although this is reduced by the lower oil revenues for the oil exporters. In the Medium 2 ºC scenario, Other major economies have a slightly lower increase in net revenues as a result of emission trading being introduced in China. These changes are shown before any transfers of funds from OECD to developing countries to fund the additional low-GHG investment projects.

Table 8: Effects of policy scenarios on government balances difference from reference case

	Scenario	OECD+	Other major economies*	Other countries	World
Government net revenues ($bn, nominal)	450	39.1	134.9	42.3	216.3
Government net revenues ($bn, nominal)	Medium 2ºC	71.5	118.4	53.1	243.0
Government net revenues (% GDP, nominal)	450	0.07	0.61	0.26	0.23
Government net revenues (% GDP, nominal)	Medium 2ºC	0.13	0.54	0.32	0.26

OECD+: all OECD and non-OECD EU countries.

*Other major economies: Brazil, China, the Middle East, Russia but *not* South Africa. This is because South Africa falls under the ‘rest of world’ region within E3MG.

6. Conclusions

This paper has adopted the conventional approach to modelling climate change mitigation by setting aside the primary benefit of reduced long-term impacts from global warming and the co-benefits of reduced air pollution and the like. Instead the focus is on macroeconomic and GHG effects over the period to 2020 following the Great Recession and subsequent high unemployment in OECD economies. We have used a “new economics” model to assess the effects of the policies in the 450 scenario prepared for the G20 by the International Energy Agency (IEA WEO, 2010).

Five conclusions can be drawn from this research.

1. The IEA's 450 scenario does not appear to be sufficiently strong to have a reasonable chance of achieving the 2ºC target over the 21st century. We find that an extra 20% of the 450 investment and an emission trading scheme in China brought forward from 2021 to 2013 will give a medium chance (50-66%) of achieving the target. Much stronger policies will be needed to give a likely (greater than 66%) chance.
2. Some form of carbon pricing is needed for economic efficiency and to offset any rebound effect from energy efficiency policies alone. The rise in prices for fossil-fuel electricity is critical in providing incentives for installation of low-GHG technologies and saving of electricity by households and business.
3. The reduction in oil prices following reduced demand for oil in the 450 policy scenario is an important contribution to the increase economic activity in oil-importing countries and as an offset to the effects from carbon price increases and the removal of fossil-fuel subsidies.
4. Additional employment from policies for decarbonisation is concentrated in the construction, agriculture and forestry sectors, because manufacturing is much less employment-intensive.
5. There could be small but beneficial effects to the global economy from implementing the policies designed to limit temperature change to 2ºC, with employment over 1.5% higher than the reference level by 2020. The effect is excluded from traditional equilibrium models of policies dominating the literature, but evident with a demand-led approach to growth, which allows for the additional investment to utilise resources that would otherwise be unemployed. Not unexpectedly, there are both winners and losers in the scenarios. In particular sectors and countries that specialise in the production of investment goods stand to benefit, while energy sectors and the OPEC members would lose out from reduced demand for energy.

7. References

Barbier, Edward (2009), *A Global Green New Deal*. UNEP, February.

Barbier, Edward (2010a), How is the Global Green New Deal going*?*. *Nature* 464 pp. 832-833.

Barbier, Edward (2010b), *A Global Green New Deal: rethinking the economic recovery*. May.

Barker, T. (2008). 'The economics of dangerous climate change". Special Issue of Climatic Change on "The Stern Review and its Critics". *Climatic Change*, 89, 173–194

Barker, Terry, Athanasios Dagoumas and Jonathan Rubin (2009) 'The macroeconomic rebound effect and the world economy'. *Energy Efficiency* 2(4) pp 411-427. doi: 10.1007/s12053-009-9053-y

Barker, T. (2011). 'Towards a 'new economics': values, resources, money, markets, growth and policy', chapter 2, pp. 39-76 in Philip Arestis and Malcolm Sawyer (eds) *New Economics as Mainstream Economics,* Palgrave Macmillan.

Barker, T., Pan, H., Köhler, J., Warren, R. and Winne, S. (2006). Decarbonizing the Global Economy with Induced Technological Change: Scenarios to 2100 using E3MG. *The Energy Journal* 27: 241-258

Barker, T. and S. Scrieciu (2010). 'Modeling low stabilization with E3MG: towards a "New Economics" approach to simulating Energy-Environment-Economy system dynamics', *Energy Journal* Special Issue on "The Economics of Low Stabilisation", January 2010, pp.137-164.
Bowen, Alex, Sam Fankhauser, Nicholas Stern and Dimitri Zenghelis, An outline of the case for a 'green stimulus'. Grantham Institute on Climate Change and the Environment, February 2009.
CCICED China Council for International Cooperation on Environment and Development (2009) Task Force Report on China's Pathway Towards a Low Carbon Economy. http://www.wbcsd.org/DocRoot/il06d7JhY0QCBMIsUq1h/CCICED_LCE_Full_Report-FINAL%20%282%29.pdf
Edenhofer, Ottmar and Nicholas Stern (2009), *Towards a Global Green Recovery, Recommendation for Immediate G20 Action*. March.
Holt R (2007). What is Post Keynesian economics? In: Forstater M, Mongiovi G, Pressman S (eds*) Post Keynesian Macroeconomics*. Routledge, London
International Energy Agency (2010). *World Energy Outlook* 2010 (IEA WEO 2010). IEA, Paris.
IPCC AR4. (2007). *IPCC Fourth Assessment Report*. http://www.ipcc.ch/
Kaldor, N. (1957). "A model of economic growth". *Economic Journal* 67: 591-624.
Kaldor, N. (1972). "The irrelevance of equilibrium economics". *Economic Journal* 52: 1237-55.
Kaldor, N. (1985). *Economics without Equilibrium*. UK: Cardiff Press.
New Economics Foundation (2008), *A Green New Deal*. July.
Pollin, Robert, Heidi Garrett-Peltier, James Heintz, and Helen Scharber. 2008. *Green Recovery: A Programme to Create Good Jobs and Start Building a Low-Carbon Economy.* Center for American Progress, Washington DC
Pollitt, H and Junankar, S (2009) 'The Impact of Oil Prices on the Global Economic Recovery: an assessment under alternative recovery scenarios'. Special report to the UK FCO for the April 2009 London G20 summit, Cambridge Econometrics.
Scott M. (1989). *A New View of Economic Growth*. Oxford: Clarendon Press.
Setterfield M. eds. (2002). *The Economics of Demand-led Growth – Challenging the Supply-side Vision of the Long Run*. Cheltenham, UK: Edward Elgar.
Spilimbergo, Antonio, Steve Symansky, Oliver Blanchard and Carlo Cottarelli, Fiscal Policy for the Crisis. *IMF Staff Position Note*, December 2008
Stern Review on the Economics of Climate Change (2006). HM Treasury.
UNEP United Nation Environment Programme (2009a) *Global Green New Deal Policy Brief*. March.
UNEP United Nation Environment Programme (2009b) *Global Green New Deal An Update for the G20 Pittsburgh Summit.* September.
UNEP United Nation Environment Programme (2010) *The Emissions Gap Report Are the Copenhagen Accord Pledges Sufficient to Limit Global Warming to 2° C or 1.5° C? A preliminary assessment.* November, UNEP, Paris. www.unep.org\publications\ebooks\emissionsgapreport
UNEP United Nation Environment Programme (2011) *Towards a Green Economy Pathways towards sustainable development and poverty eradication*. www.unep.org\greeneconomy
US EIA Energy Information Administration (2010) *International Energy Statistics*. http://www.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8