Centre of Policy Studies Working Paper

No. G-244 September 2014

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ISSN 1 031 9034

ISBN 978-1-921654-54-1

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Abstract

Reducing greenhouse gas emissions without reducing economic growth requires advances in technology (which reduce the emissions intensity of industrial production) and/or policy measures to promote structural change (which shift the composition of production in favour of less polluting industries). Moreover, both methods of mitigating the effect of the gases must inevitably proceed in an environment of structural change driven by a variety of other economic forces. This paper introduces new economic modelling which permits an analysis of the effects of mitigation policy on employment that is firmly located within the historical structure of the economy, and within its likely future development in the medium term.

Specifically, the paper investigates the imposition of a tax on the employment of labour by each industry in proportion to the emissions per hour of employment in the industry. In this approach, the extent to which the job of a particular worker can be considered to be "green" depends on the industry in which he/she works and not on his/her occupation or skill level. The effects of imposing the tax are reported as deviations from the current CEDEFOP medium-term employment forecasts for the European Union. The analysis uses a CGE labour market extension to the macro-econometric E3ME model. The tax is assumed to be returned to producers in such a way that aggregate employment remains constant, so the focus of the analysis is on the structural, rather than the secular, implications of mitigation policy for employment growth.

The model incorporates a detailed description of the structure of the labour market, identifying cross-classified employment in 41 industries, 27 occupations and 3 skill levels. Hence it allows for a comprehensive, cohesive assessment of the economy's requirements for "green" skills in the sense that it determines which occupations/skill levels expand, and which contract, in response to the mitigation policy. This kind of comparison is important for assigning the appropriate weight to training programs that allocate resources to green skills rather than alternative objectives of educational policy.

The analysis in the paper is restricted to the United Kingdom but the model is designed to provide a suitable basis for comparative-dynamic labour market analyses for all countries belonging to the European Union.

JEL codes: C68, D33, D58, I29, J23, O52, Q52

Keywords: CGE modelling, climate change mitigation, distribution of employment, green jobs

Contents

1. Introduction

If a labour market policy is going to reduce greenhouse gas emissions, its effect must fall into one or more of three broad categories. It must result in a reduction of aggregate employment, in technical change which reduces emissions with no change in employment, or in a change in the distribution of employment in favour of industries with relatively low emission intensity. Policies designed to promote "green jobs" tend to fall into the last of these categories.

In a high-profile joint report by the United Nations Environment Program (2008), green jobs were defined as

"work in agricultural, manufacturing, research and development (R&D), administrative, and service activities that contribute substantially to preserving or restoring environmental quality. Specifically, but not exclusively, this includes jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high efficiency stra; de-carbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution." (p.3)

The report suggests (p.5) the following policies to drive employment in green jobs.

- Subsidies. Phase out subsidies for environmentally harmful industries, and shift a portion or all of those funds to renewable energy, efficiency technologies, clean production methods, and public transit.
- Carbon Markets. Fix the current shortcomings inherent in carbon trading and Kyoto Protocol related innovations like the Clean Development Mechanism so that they can become reliable and adequate funding sources for green projects and employment.
- Tax Reform. Scale up eco-taxes, such as those adopted by a number of European countries, and replicate them as widely as possible. Eco-tax revenues can be used to lighten the tax burden falling on labor while discouraging polluting and carbon-intensive economic activities.
- Targets and Mandates. Ensure that regulatory tools are used to the fullest extent in the drive to develop greener technologies, products, and services—and thus green employment. This includes land-use policies, building codes, energy-efficiency standards (for appliances, vehicles, etc.), and targets for renewable energy production.
- Energy Alternatives. Adopt innovative policies to overcome barriers to renewable energy development, including feed-in laws that secure access to the electrical grid at guaranteed prices.
- Product Takeback. Adopt "extended producer responsibility" laws (requiring companies to take back products at the end of their useful life) for all types of products.

- Eco-Labeling. Adopt eco-labels for all consumer products to ensure that consumers have access to information needed for responsible purchasing decisions (and hence encouraging manufacturers to design and market more eco-friendly products).

- R&D Budgets. Reduce support for nuclear power and fossil fuels and provide greater funding for renewable energy and efficiency technologies.

- International Aid. Reorient the priorities of national and multilateral development assistance agencies as well as export credit agencies away from fossil fuels and large-scale hydropower projects toward greener alternatives.

Clearly, the primary motivation of many of these policies is to induce producers and/or consumers to change their behaviour so that employment is redistributed in favour of green jobs.

In many analyses of green jobs, and certainly in the UNEP report, it is implicit that "greenness" can be identified as an intrinsic property of each job taken separately. However, employment in a particular job is connected to a greater or lesser extent to employment in all other jobs via the markets for labour. These market linkages may subvert the objectives of employment policies if those policies are pursued in isolation from one another. It is the contention of this paper that policies designed to mitigate climate change are unlikely to be successful if they are pursued on a job-by-job or case-study basis. Furthermore, labour market linkages are also likely to be important for the formulation of training policies intended to support the transition to a green economy.

Here, the effects of labour market linkages are investigated in a more restricted environment than that considered in the UNEP report. Specifically, a green job is taken to be one which is responsible for the emission of a relatively small amount of greenhouse gases per hour of employment. To promote employment in green jobs thus defined, a tax is imposed on the employment of labour by industries in proportion to the amount of greenhouse gases they emit. The effects of imposing the tax are reported as deviations from the CEDEFOP medium-term employment forecasts for the United Kingdom described in Wilson *et al*. (2010). The model used is a revised version of the CGE labour market extension to the Cambridge Econometrics E3ME model described in Meagher et al. (2012). The tax is assumed to be returned to producers in such a way that aggregate employment remains unchanged, so the focus of the analysis is on the structural, rather than the secular, implications of mitigation policy for employment growth.

The remainder of the paper is organised as follows. Section 2 describes the method for determining the emission intensity of employment. Section 3 introduces the adjustments to the model required to impose the taxes on employment. Section 4 presents results and Section 5 contains some concluding remarks.

2. Emission Intensities

The emission intensities used in this paper are adapted from data prepared for a major study of climate change mitigation undertaken by the Australian Treasury (2008). The original data consists of estimates of the amount of greenhouse gases emitted by each industry per unit of its output. Column 1 of Table 1 shows forecasts for these emission intensities for 2009-10 undertaken at the time of the study based on the original data. Emissions are measured in kilotonnes of CO_2 equivalent. The unit of output is the amount that could be bought for $1millon in 2009-10.

According to column 1, the industry *27 Aluminium* is only a moderate emitter of greenhouse gases (rank 12). However, the industry uses large amounts of *32 Electricity* in its production, and *Electricity* has the highest emission intensity. Hence, a better indicator of the influence of the various industries on atmospheric pollution can be obtained by attributing the emissions associated with the production of intermediate inputs to the using industry. This is done in column 3 of Table 1. According to the adjusted emission intensities, *Aluminium* rather than *Electricity* is the worst polluter. The intensity for *Electricity* is more than halved, with significant electricity-related emissions now being attributed to *51 Private Electricity* and *52 Private Heating* as well as to *Aluminium*. Similarly, some of the emissions produced by *1 Sheep and Cattle* are attributed to *14 Meat products* and *16 Textiles, Clothing and Footwear*, some produced by *2 Dairy* are attributed *15 Other Food Products*, and some produced by *33 Gas Supply* are attributed to *52 Private Heating*. On the other side of the pollution ledger, some of the reduction in emissions resulting from production in the industry *7 Forestry* are now attributed to the industries which use forestry products as inputs, particularly *17 Wood Products* and *18 Paper Products*. The change to the accounting system reduces the range of the emission intensities by more than half.

As indicated in the Introduction, policy proposals for climate change mitigation are often based on identifying jobs that can be considered to be "green" in some *a priori* sense. Once identified, the jobs are then recommended for government support of one kind or another as a way of reducing emissions. However, as the UNEP example shows, the definition of greenness can be quite loose. It may reasonably be thought that an employment classification based on emission intensities would provide a more rigorous definition of "greenness", and hence provide a more reliable guide as to the contributions that various jobs might make to the mitigation process.

Table 1. Emission Intensities, Australia, 2009-10.

Code	Industry	(1) Direct Intensities: Intensity	(2) Direct Intensities: Rank	(3) Adjusted Intensities: Intensity	(4) Adjusted Intensities: Rank
1	Sheep and Cattle	4.286	2	1.489	6
2	Dairy	1.837	3	0.380	14
3	Other Animal Farming	0.983	8	0.278	20
4	Grains	0.231	21	0.168	30
5	Other Agriculture	0.417	18	0.252	23
6	Agricultural Services and Fishing	0.112	29	0.129	32
7	Forestry	-5.598	52	-2.110	52
8	Coal	0.839	9	0.850	10
9	Oil	0.113	28	0.012	47
10	Gas	0.754	13	0.339	17
11	Iron Ores	0.049	34	0.092	38
12	Non-ferrous Metal Ores	0.209	23	0.212	26
13	Other Mining	0.073	31	0.052	45
14	Meat Products	0.008	46	1.913	3
15	Other Food Products	0.034	36	0.264	21
16	Textile, Clothing and Footwear	0.033	37	0.469	11
17	Wood Products	0.040	35	-0.324	51
18	Paper Products	0.199	24	-0.074	50
19	Printing	0.008	45	0.065	42
20	Refinery Products	0.464	16	0.104	35
21	Chemicals	0.210	22	0.192	28
22	Rubber and Plastic Products	0.110	30	0.127	33
23	Non-metal Construction Products	0.431	17	0.207	27
24	Cement	1.554	5	0.435	12
25	Iron and Steel	0.815	10	0.433	13
26	Alumina	1.425	6	1.520	5
27	Aluminium	0.755	12	2.849	1
28	Other Metals Manufacturing	0.154	27	0.296	19
29	Metal Products	0.005	48	0.250	24
30	Motor Vehicles and Parts	0.003	49	0.097	37
31	Other Manufacturing	0.017	42	0.130	31
32	Electricity Supply	4.369	1	2.078	2
33	Gas Supply	0.809	11	0.065	41
34	Water Supply	0.032	38	0.299	18
35	Construction	0.010	43	0.091	39
36	Trade	0.029	40	0.085	40
37	Accommodation and Hotels	0.022	41	0.119	34
38	Road Transport, Passengers	1.697	4	0.875	9
39	Road Transport, Freight	0.710	15	0.367	16
40	Rail Transport, Passengers	0.274	19	0.379	15

...continued

Table 1. (continued)

Code	Industry	(1) Direct Intensity	(2) Direct Rank	(4) Direct and Indirect Intensity	(5) Direct and Indirect Rank
41	Rail Transport, Freight	0.166	26	0.188	29
42	Water Transport	0.052	33	0.097	36
43	Air Transport	0.249	20	0.255	22
44	Community Services	0.031	39	0.058	43
45	Financial Services	0.000	51	0.003	49
46	Business Services	0.006	47	0.044	46
47	Ownership of Dwelling	0.000	50	0.011	48
48	Public Services	0.009	44	0.053	44
49	Other Services	0.177	25	0.213	25
50	Private Transport	1.092	7	1.116	8
51	Private Electricity	0.062	32	1.375	7
52	Private Heating	0.717	14	1.901	4
53	All Industries	0.218		0.218	

Notes. Intensities are expressed as emissions per unit output. Emissions are measured in kilotonnes of CO_2 equivalent. The unit of output is the amount that can be bought for $1millon in 2009-10. Adjusted intensities are obtained by attributing the emissions associated with the production of intermediate inputs to the using industry.

The first step in determining a suitable classification is to convert the output intensities by industry in Table 1 into employment intensities by industry using Australian data on labour-output ratios in 2009-10. These intensities are then assumed to apply equally to the United Kingdom in 2009. The industry classification used in the CEDEFOP forecasts for the U.K. can be made to conform to the Australian classification if both are first aggregated to a common classification containing 30 industries. The results are shown in Table 2, where the same intensity has been assigned to U.K. industries which are combined in the common classification.

Greenhouse gases are emitted by industries. Hence the emission intensity of an hour of labour is taken to depend only on the industry in which it is employed and not on the occupation or skill of the associated worker. In Table 3, this assumption has been used to convert the employment intensities by industry in Table 2 into employment intensities by occupation. The range is again reduced significantly due to averaging.

In column 4 of Table 3, the occupations have been ranked from most polluting (*22 Stationary plant and related operators*) to least polluting (*1 Armed forces*) according to their emission intensities. It is this ranking which determines the “greenness” of an occupation for purposes of the present analysis.

Table 2. Emission Intensities Per Unit Labour Input by Industry, United Kingdom, 2009.

Code	Industry	(1) Direct Intensity	(2) Direct Rank	(3) Adjusted Intensity	(4) Adjusted Rank
1	Agriculture etc	0.1106	10	0.0363	15
2	Coal	0.9064	3	0.8212	3
3	Oil & Gas etc	2.0755	2	1.2522	2
4	Other Mining	0.0657	13	0.0618	12
5	Food, Drink & Tobacco	0.0092	20	0.2098	6
6	Textiles, Clothing & Leather	0.0041	23	0.0533	13
7	Wood & Paper	0.0168	19	-0.0267	41
8	Printing & Publishing	0.0013	28	0.0098	30
9	Manufactured Fuels	0.7163	4	0.1434	7
10	Pharmaceuticals	0.0994	12	0.0815	10
11	Chemicals nes	0.0994	11	0.0815	9
12	Rubber & Plastics	0.0255	14	0.0262	20
13	Non-Metallic Mineral Products	0.1536	7	0.0472	14
14	Basic Metals	0.3126	5	0.3946	4
15	Metal Goods	0.0007	37	0.0312	19
16	Mechanical Engineering	0.0007	36	0.0312	18
17	Electronics	0.0007	35	0.0312	17
18	Electrical Eng. & Instruments	0.0007	34	0.0312	16
19	Motor Vehicles	0.0006	39	0.0171	28
20	Other Transport Equipment	0.0006	38	0.0171	27
21	Manufacturing nes	0.0026	24	0.0180	25
22	Electricity	2.3266	1	1.2879	1
23	Gas Supply	0.2383	6	0.0171	26
24	Water Supply	0.0084	21	0.0692	11
25	Construction	0.0010	32	0.0086	32
26	Distribution	0.0025	26	0.0063	37
27	Retailing	0.0025	25	0.0063	36
28	Hotels & Catering	0.0018	27	0.0090	31
29	Land Transport etc	0.1312	9	0.0961	8
30	Water Transport	0.1459	8	0.2420	5
31	Air Transport	0.0210	15	0.0192	24
32	Communications	0.0066	22	0.0109	29
33	Banking & Finance	0.0000	41	0.0006	40
34	Insurance	0.0000	40	0.0006	39
35	Computing Services	0.0010	31	0.0074	35
36	Professional Services	0.0010	30	0.0074	34
37	Other Business Services	0.0010	29	0.0074	33
38	Public Administration & Defence	0.0007	33	0.0033	38
39	Education	0.0179	18	0.0204	23
40	Health & Social Work	0.0179	17	0.0204	22
41	Miscellaneous Services	0.0179	16	0.0204	21
42	All industries	0.0246		0.0246	

Notes. Emissions are measured in kilotonnes of CO_2 equivalent. Labour is measured in thousands of hours. Adjusted intensities are obtained by attributing the emissions associated with the production of intermediate inputs to the using industry.

Table 3. Emission Intensities Per Unit Labour Input by Occupation, United Kingdom, 2009.

Code	Occupation	(1) Direct Intensity	(2) Direct Rank	(3) Adjusted Intensity	(4) Adjusted Rank
1	Armed Forces	0.0026	27	0.0057	27
2	Legislators and senior officials	0.0125	24	0.0137	25
3	Corporate managers	0.0237	13	0.0242	13
4	Managers of small enterprises	0.0149	21	0.0161	23
5	Physical, mathematical and engineering science Professionals	0.0407	7	0.0342	7
6	Life science and health professionals	0.0197	17	0.0209	17
7	Teaching professionals	0.0192	18	0.0209	16
8	Other professionals	0.0131	23	0.0157	24
9	Physical and engineering science associate Professionals	0.0361	9	0.0325	8
10	Life science and health associate professionals	0.0206	15	0.0203	19
11	Teaching associate professionals	0.0205	16	0.0237	14
12	Other associate professionals	0.0154	20	0.0174	22
13	Office clerks	0.0216	14	0.0208	18
14	Customer services clerks	0.0415	6	0.0313	10
15	Personal and protective services workers	0.0158	19	0.0188	20
16	Models, salespersons and demonstrators	0.0046	26	0.0082	26
17	Skilled agricultural and fishery workers	0.0824	3	0.0309	11
18	Extraction and building trades workers	0.0245	11	0.0227	15
19	Metal, machinery and related trades workers	0.0416	5	0.0407	5
20	Precision, handicraft, craft printing and related trades workers	0.0296	10	0.0243	12
21	Other craft and related trades workers	0.0095	25	0.0439	4
22	Stationary plant and related operators	0.1147	1	0.0754	1
23	Machine operators and assemblers	0.0243	12	0.0722	2
24	Drivers and mobile plant operators	0.0712	4	0.0576	3
25	Sales and services elementary occupations	0.0143	22	0.0177	21
26	Agricultural, fishery and related labourers	0.0899	2	0.0324	9
27	Labourers in mining, construction, manufacturing and transport	0.0361	8	0.0394	6
28	All occupations	0.0246		0.0246	

Notes. Emissions are measured in kilotonnes of CO_2 equivalent. Labour is measured in thousands of hours. Adjusted intensities are obtained by attributing the emissions associated with the production of intermediate inputs to the using industry.

3. Adapting the MLME model

The CEDEFOP labour market forecasts referred to in the Introduction were produced using a modular modelling approach containing two major components:

- an multi-sector macroeconomic model of 29 European countries (E3ME), primarily developed and operated by Cambridge Econometrics, and
- a labour market extension, referred to as the Warwick Labour Market Extension (WLME), primarily developed and operated by the Institute for Employment Research at the University of Warwick.

The countries are treated as an integrated system in E3ME but the extension is applied to each country separately. Forecasts of employment by industry are determined by E3ME; forecasts of employment by occupation and qualification are determined by WLME.

In the simulations reported here, the WLME has been replaced with an alternative extension which uses computable general equilibrium (CGE) modelling techniques. This extension has been developed primarily at the Centre of Policy Studies at Monash University and is referred to as the Monash Labour Market Extension (MLME). Compared to the WLME, MLME relies less on time series extrapolation and more on explicitly modelled economic behaviour. It describes the operation of 27 occupational labour markets. On the demand side of these markets, labour belonging to different occupations can be converted into effective units of industry specific labour according to Constant Elasticity of Substitution (CES) functions. On the supply side, labour by skill can be converted into labour by occupation according to Constant Elasticity of Transformation (CET) functions. Relative wage rates are assumed to adjust to clear the markets for labour by occupation. The complete set of equations which makes up the MLME model is set out in Meagher et al. (2012).

The WLME includes a module which “balances” the demand for labour by occupation derived from the E3ME forecasts with the supply of labour by occupation derived from separate projections of employment by skill. If the balanced E3ME-WLME forecast is interpreted as a market clearing forecast, technical change can be introduced into MLME such that E3ME-MLME reproduces the CEDEFOP forecasts. This procedure is described in Meagher et al. (2013). The CEDEFOP forecasts constitute the Basecase simulation in the present analysis.

The Basecase is to be compared to a Mitigation scenario in which taxes are introduced to induce a change in employment away from industries producing high levels of emissions. To that end, two new equations are introduced into MLME:

Equation 1: Demand for labour by industry i

$$d_i = d - \sigma^S [p2_i - \sum_{k=1}^{IND} SH_k \; p2_k] + a_i - \sigma^S [a_i - \sum_{k=1}^{IND} SH_k \; a_k] \qquad \text{(all } i \in IND\text{)}$$

where

d_i is the change in demand for labour by industry *i*,

d is the change in demand for labour by all industries,

$p2_i$ is the change in the average hourly wage rate (tax inclusive) for labour in industry i,

SH_i is the share of industry i in total cost of employing labour,

σ^S is the elasticity of substitution of labour between industries,

a_i is industry-i-augmenting technical change in employment.

Equation 2: Tax inclusive average wage rate for labour in industry i

$$p2_i = SH_i^P \; p1_i + SH_i^T \; t_i \qquad \text{(all } i \in IND\text{)}$$

where

$p1_i$ is the change in the average hourly wage rate (tax exclusive) for labour in industry i,

t_i is the change in the specific tax on employment in industry *i,*

SH_i^P is the tax-exclusive cost of employing labour in industry i as a share of the total cost,

SH_i^T is the tax on employing labour in industry i as a share of the total cost.

The equations in MLME are expressed in terms of percentage changes of the variables. That is, the system computes the percentage changes in the endogenous variables in some period arising from changes ("shocks") to the exogenous variables. The coefficients in the system are shares. Sets, coefficients and parameters are denoted by upper-case or Greek symbols. The convention is adopted that lower-case symbols denote percentage changes in the levels of the variables represented by the corresponding upper case symbols, that is, the notation assumes y=100 (dY/Y). The levels variables Y do not appear in the equations but they will be used in the discussion which follows.

Equation 1 maintains that, if there is no technical change (i.e., the a_i are all zero) and if there are no changes in the relative wage rates $P2_i$ (i.e., the $p2_i$ are all zero), a one per cent increase in the aggregate demand D for labour leads to a one per cent increase in the demand D_i for labour by each industry *i*. If, however, the average wage rate $P2_i$ for industry i rises relative to the aggregate wage rate, i.e., if

$$p2_i > \sum_{k=1}^{IND} SH_k \; p2_k \,,$$

the demand D_i by industry i will increase less rapidly than *D*. Employment will be substituted against industry i in favour of other industries. If substitution is difficult, i.e., if the elasticity of substitution σ^S is small, the amount by which *d* exceeds d_i will also tend to be small. Note that wage cost shares are to be used in computing the aggregate wage rate for industry *i*, i.e.,

$$SH_k = P_k \; D_k \; / \sum_{l=1}^{IND} P_l \;\; D_l \,.$$

Now suppose that the wage rates P_k and the aggregate demand *D* are constant but technical change is taking place. If the change is *i*-augmenting at the rate of one per cent, (i.e., $a_i = -1$ and $a_k = 0$ for $k \neq i$ *),* then demand for labour by industry *i* falls by $(1 - \sigma^S (1 - SH_i))$ per cent, i.e. by less than one per cent. Thus the *i*-augmenting technical progress induces some substitution in favour of industry i and away from industry *k* , *k ≠ o*. Note that the demand for labour by industry *k* , *k ≠ i*, falls by $\sigma^S \; SH_i$ per cent.

If employment by industry is set at the levels forecast by E3ME and the a_k made endogenous, MLME determines the technical change regime $\hat{a}_k$, say, implicit in those forecasts. That is, if the a_k are set at the levels so determined, MLME will reproduce the E3ME industry forecasts. In the forecasts reported in the next section, a_k is always set equal to $\hat{a}_k$.

In Equation 2, the change $p1_i$ in the wage rate $P1_i$ for industry *i* is obtained by averaging the changes in the market-clearing occupational wage rates using the relevant cost shares for the industry. The change $p2_i$ in the wage rate $P2_i$ is obtained by taking a weighted sum of $p1_i$ and the change t_i in the specific tax levied against employment in industry i. The total tax on employment is set at five per cent of the total (tax exclusive) cost of employing labour. It is distributed between the industries in proportion to their emission levels as determined by the intensities shown in column 3 of Table 2 and their employment levels in each year of the Basecase scenario.

4. The Effects of Mitigation

Consider first the effects of the emission taxes on employment by industry. Table 4 *compares* employment growth for the United Kingdom between 2009 and 2020 in the Basecase and Mitigation scenarios. The most important change occurs for *22 Electricity*. In the Basecase, employment in this industry contracts by 18.85 per cent. In the Mitigation scenario, the contraction increases to 45.81 per cent. Significant declines in employment also occur for *3 Oil and Gas* (- 52.46 per cent to -66.62 per cent), *14 Basic Metals* (-33.48 per cent to -44.30 per cent), *30 Water Transport* (-6.67 per cent to -14.28 per cent) and *2 Coal* (-30.05 per cent to -39.30 per cent). These five industries have the highest emission intensities as listed in column 4 of Table 2.

The industries which benefit the most from mitigation in terms of employment are *7 Wood and Paper*, *19 Motor Vehicles*, *34 Insurance*, 33 *Banking and Finance* and *38 Public Administration and Defence*. Four of these industries appear at the bottom of the ranking in column 4 of Table 2, the odd one out being motor vehicles.

Table 4. Employment Growth by Industry, United Kingdom, 2009-2020, Per Cent.

Code	Industry	(1) Basecase Scenario Growth	(2) Basecase Scenario Rank	(3) Mitigation Scenario Growth	(4) Mitigation Scenario Rank
1	Agriculture etc	-8.60	23	-11.06	25
2	Coal	-30.05	39	-39.30	38
3	Oil & Gas etc	-52.46	41	-66.62	41
4	Other Mining	-8.95	24	-8.90	22
5	Food, Drink & Tobacco	-26.38	34	-30.90	37
6	Textiles, Clothing & Leather	-27.30	36	-26.65	34
7	Wood & Paper	7.14	7	10.52	6
8	Printing & Publishing	-3.15	18	-2.19	16
9	Manufactured Fuels	-14.96	28	-14.24	27
10	Pharmaceuticals	-27.96	37	-27.23	35
11	Chemicals nes	-12.25	27	-12.39	26
12	Rubber & Plastics	-26.75	35	-25.79	33
13	Non-Metallic Mineral Products	1.87	13	1.49	13
14	Basic Metals	-33.48	40	-44.30	39
15	Metal Goods	-15.36	29	-15.73	30
16	Mechanical Engineering	9.49	6	8.86	7
17	Electronics	26.03	1	25.38	2
18	Electrical Eng. & Instruments	-10.29	25	-9.75	23
19	Motor Vehicles	-12.14	26	-10.70	24
20	Other Transport Equipment	-29.73	38	-29.00	36
21	Manufacturing nes	-22.91	33	-22.29	32
22	Electricity	-18.85	31	-45.81	40
23	Gas Supply	-20.23	32	-19.40	31
24	Water Supply	-2.73	17	-4.09	20
25	Construction	1.87	14	2.71	12
26	Distribution	2.14	11	2.94	11
27	Retailing	11.85	5	12.37	5
28	Hotels & Catering	-2.30	16	-2.27	17
29	Land Transport etc	2.02	12	-0.44	15
30	Water Transport	-6.67	22	-14.28	28
31	Air Transport	-5.05	21	-4.19	21
32	Communications	2.47	10	3.24	10
33	Banking & Finance	4.17	9	5.39	9
34	Insurance	-16.87	30	-15.47	29
35	Computing Services	6.14	8	6.89	8
36	Professional Services	21.43	4	21.92	4
37	Other Business Services	25.58	3	26.12	1
38	Public Administration & Defence	-4.72	20	-3.70	19
39	Education	-3.29	19	-3.34	18
40	Health & Social Work	0.63	15	0.10	14
41	Miscellaneous Services	25.73	2	25.26	3
42	All industries	4.82		4.82	

The effect of mitigation on industry employment, then, can be largely understood in terms of the emission intensities of industry employment. However, employment taxes are levied against emission levels rather than emission intensities. Further, from Equation 2 in Section 3, the changes $p1_i$ in tax-exclusive wage rate contribute to changes $p2_i$ in the tax-inclusive ware rate, as well as changes t_i in the tax itself. Since it is the tax-inclusive wage rates that determine the redistribution of employment between industries, the ranking of changes in employment does not reproduce the ranking of emission intensities precisely.

The emission intensities are assumed to remain constant during the period 2009 to 2020. Hence the change in emissions for each industry over the period is given by the relevant employment growth rate shown in Table 4. In the Basecase, aggregate emissions fall by 6.03 per cent. The effect of the taxes is to increase this reduction to 11.59 per cent. In 2020, emissions are 5.92 per cent smaller in the Mitigation scenario than they are in the Basecase. Table 5 shows the contributions made by each industry to this difference. The contributions are dominated by *22 Electricity* which accounts for 3.53 percentage points (or 59.55 per cent) of the total reduction of 5.92 per cent.

The effects of mitigation on employment by occupation are shown in Table 6. As some workers belonging to a particular occupation tend to be employed in industries which expand while others are employed in industries which contract, the imposition of the tax has comparatively little impact on the distribution of employment across occupations. Hence the relative growth rates in the Mitigation scenario are quite similar to those for the Basecase. The occupations most affected are the ones for which employment is relatively concentrated in single industries and hence are less exposed to the averaging process. Thus, the occupation *17 Skilled agricultural and fishery workers* suffers the largest fall in employment (i.e, a fall of 1.40 percentage points from -4.79 per cent in the Basecase to -6.19 per cent in the Mitigation Scenario) because two thirds of its employment is provided by the single industry *1 Agriculture*. Similarly, the occupation *1 Armed Forces* enjoys the largest increase of 1.73 percentage points because more than ninety percent of its workers are employed in the single industry *38 Public Administration and Defence*. Note that the industry *22 Electricity*, for which the change in employment of -26.96 percentage points is larger than that of any other industry, does not play any significant role in determining the rankings In Table 6. This is because it supplies no more than about one percent of employment for any of the 27 occupations.

Table 5. Change in Emissions due to Mitigation, United Kingdom, 2020

	Industry	(1) Basecase Emission Shares (per cent)	(2) Change in Emissions (per cent)	(3) Contributions to Change: Percentage Points	(4) Contributions to Change: Per Cent
1	Agriculture etc	3.05	-2.68	-0.08	1.38
2	Coal	0.71	-13.21	-0.09	1.59
3	Oil & Gas etc	2.80	-29.77	-0.83	14.07
4	Other Mining	0.22	0.06	0.00	0.00
5	Food, Drink & Tobacco	7.95	-6.13	-0.49	8.24
6	Textiles, Clothing & Leather	0.70	0.91	0.01	-0.11
7	Wood & Paper	-0.60	3.17	-0.02	0.32
8	Printing & Publishing	0.39	1.00	0.00	-0.07
9	Manufactured Fuels	0.48	0.86	0.00	-0.07
10	Pharmaceuticals	0.47	1.02	0.00	-0.08
11	Chemicals nes	1.27	-0.15	0.00	0.03
12	Rubber & Plastics	0.42	1.32	0.01	-0.09
13	Non-Metallic Mineral Products	0.79	-0.36	0.00	0.05
14	Basic Metals	2.60	-16.25	-0.42	7.13
15	Metal Goods	1.22	-0.42	-0.01	0.09
16	Mechanical Engineering	1.49	-0.56	-0.01	0.14
17	Electronics	0.43	-0.50	0.00	0.04
18	Electrical Eng. & Instruments	0.86	0.61	0.01	-0.09
19	Motor Vehicles	0.30	1.65	0.00	-0.08
20	Other Transport Equipment	0.26	1.04	0.00	-0.05
21	Manufacturing nes	0.37	0.81	0.00	-0.05
22	Electricity	10.61	-33.21	-3.53	59.55
23	Gas Supply	0.03	1.05	0.00	-0.01
24	Water Supply	0.33	-1.39	0.00	0.08
25	Construction	2.63	0.84	0.02	-0.37
26	Distribution	1.76	0.79	0.01	-0.23
27	Retailing	2.80	0.48	0.01	-0.23
28	Hotels & Catering	2.86	0.04	0.00	-0.02
29	Land Transport etc	18.12	-2.40	-0.44	7.35
30	Water Transport	0.68	-8.14	-0.06	0.93
31	Air Transport	0.25	0.92	0.00	-0.04
32	Communications	0.80	0.76	0.01	-0.10
33	Banking & Finance	0.08	1.18	0.00	-0.02
34	Insurance	0.01	1.70	0.00	0.00
35	Computing Services	0.67	0.72	0.00	-0.08
36	Professional Services	3.31	0.42	0.01	-0.24
37	Other Business Services	3.05	0.44	0.01	-0.23
38	Public Administration & Defence	0.74	1.08	0.01	-0.14
39	Education	7.34	-0.04	0.00	0.06
40	Health & Social Work	10.63	-0.51	-0.05	0.92
41	Miscellaneous Services	7.12	-0.36	-0.03	0.43
	Total	100.00	-5.92	-5.92	100.00

Notes. Column (3) is computed from columns (1) and (2) according to (3) = (1) * (2) / 100.0. The shares in column (4) are computed from column (3).

Table 6. Employment Growth by Occupation, United Kingdom, 2009-2020, Per Cent.

		(1)	(2)	(3)	(4)
Code	Occupation	Basecase Scenario		Mitigation Scenario	
		Growth	Rank	Growth	Rank
1	Armed Forces	-48.73	27	-47.00	27
2	Legislators and senior officials	-37.77	24	-36.34	24
3	Corporate managers	8.97	9	8.94	9
4	Managers of small enterprises	6.64	10	6.64	10
5	Physical, mathematical and engineering science professionals	-2.09	15	-1.89	15
6	Life science and health professionals	29.95	3	29.49	3
7	Teaching professionals	-18.05	21	-17.51	21
8	Other professionals	23.43	4	23.38	4
9	Physical and engineering science associate professionals	5.72	11	5.67	11
10	Life science and health associate professionals	-4.66	17	-4.90	17
11	Teaching associate professionals	39.11	2	38.82	2
12	Other associate professionals	44.95	1	44.97	1
13	Office clerks	-16.08	20	-15.67	20
14	Customer services clerks	-0.66	14	-0.76	14
15	Personal and protective services workers	2.96	12	2.70	12
16	Models, salespersons and demonstrators	14.79	6	15.06	6
17	Skilled agricultural and fishery workers	-4.79	18	-6.19	18
18	Extraction and building trades workers	10.45	8	10.77	8
19	Metal, machinery and related trades workers	-27.22	23	-26.87	23
20	Precision, handicraft, craft printing and related trades workers	-42.75	26	-41.62	25
21	Other craft and related trades workers	-22.22	22	-22.23	22
22	Stationary plant and related operators	0.03	13	-0.33	13
23	Machine operators and assemblers	-6.37	19	-7.13	19
24	Drivers and mobile plant operators	13.77	7	12.83	7
25	Sales and services elementary occupations	-3.67	16	-3.61	16
26	Agricultural, fishery and related labourers	-41.79	25	-41.72	26
27	Labourers in mining, construction, manufacturing and transport	18.96	5	18.83	5
28	All occupations	4.82		4.82	

In Table 7, employment by occupation in the Basecase and Mitigation scenarios are compared for the final year 2020 of the period under consideration. Three of the occupations which suffer the largest reduction in employment due to mitigation, namely, *24 Drivers and mobile plant operators*, *23 Machine operators and assemblers* and *22 Stationary plant and related operators*, also appear at the top of the ranking in column 4 of Table 3. That is, they have the highest emission intensities. Similarly, the two occupations which enjoy the largest increase in employment, namely, *1 Armed forces* and *2 Legislative and senior officials,* also appear near the bottom of the ranking in Table 3. However, the correspondence between the two rankings is otherwise quite arbitrary. For example, the occupation with the largest fall in employment, *17 Skilled agricultural and fishery workers*, ranks only 11 with respect to emission intensity. Similarly, the occupation *19 Metal, machinery and related trades workers,* ranks 5 on emission intensity but 22 on employment.

More generally, if the occupations identified in the CEDEFOP forecasts are allocated a "greenness" property defined in terms of emission intensity, the allocation broadly fails to predict whether employment in an occupation will expand or contract when an emission reduction policy is introduced. Evidently, "greenness" should not be regarded as an intrinsic property of a job, but a property that depends on the role played by the job as the economy adjusts to the policy under consideration.

The final table, Table 8, shows the effects of mitigation on the market-clearing wage rates by occupation. Just as the employment growth rates by occupation in Table 7 are quite similar for the Basecase and Mitigation scenarios, so too are the growth rates for wages in columns 1 and 2 of Table 8. Column 3 shows the changes in the wage rates in 2020 required to clear the labour markets when the mitigation policy is introduced. For the occupation *12 Other associate professionals*, a fall in the wage rate of 4.47 per cent was required. That is, the mitigation policy resulted in a tendency towards excess supply of the occupation, a tendency that was larger than that for any other occupation. In general, a positive (negative) change in column 3 indicates that mitigation induces a tendency towards excess demand (excess supply) for the occupation, and the larger the change in the wage rate, the more pronounced is the tendency. In other words, the ranking in column 4 indicates which occupations should be targeted if training resources were to be reallocated to support of the mitigation policy.

Note that, in Table 8, the magnitude of the wage rate changes reflects the magnitudes assigned to the elasticities of substitution and transformation between occupations. The higher the elasticities, the easier it is to switch between occupations and the smaller are the wage rate changes required to clear the markets. Hence, while the qualitative policy implications of the analysis should be robust to changes in the elasticities, a systematic analysis of the sensitivity of the MLME results to such changes is clearly desirable. Such and analysis is planned for future work but, in the meantime, it would be unwise to interpret the wage rate results as unconditional forecasts.

Table 7. Employment by Occupation, United Kingdom, 2020

Code	Occupation	(1) Employment (persons) Basecase	(2) Mitigation	(3) Change in Employment (per cent)	(4) Rank
1	Armed Forces	31343	32401	3.38	27
2	Legislators and senior officials	35127	35936	2.31	26
3	Corporate managers	3912781	3911646	-0.03	13
4	Managers of small enterprises	1162209	1162179	0.00	15
5	Physical, mathematical and engineering science professionals	1144779	1147176	0.21	19
6	Life science and health professionals	566434	564446	-0.35	5
7	Teaching professionals	1103303	1110537	0.66	24
8	Other professionals	1918894	1918091	-0.04	12
9	Physical and engineering science associate professionals	762538	762157	-0.05	11
10	Life science and health associate professionals	895198	892959	-0.25	6
11	Teaching associate professionals	282439	281839	-0.21	8
12	Other associate professionals	3217417	3217861	0.01	16
13	Office clerks	2634253	2647264	0.49	23
14	Customer services clerks	935287	934338	-0.10	10
15	Personal and protective services workers	3718365	3709177	-0.25	7
16	Models, salespersons and demonstrators	1955543	1960040	0.23	20
17	Skilled agricultural and fishery workers	365800	360419	-1.47	1
18	Extraction and building trades workers	1504689	1508926	0.28	21
19	Metal, machinery and related trades workers	630823	633891	0.49	22
20	Precision, handicraft, craft printing and related trades workers	70839	72242	1.98	25
21	Other craft and related trades workers	117991	117985	0.00	14
22	Stationary plant and related operators	154053	153508	-0.35	4
23	Machine operators and assemblers	520789	516567	-0.81	3
24	Drivers and mobile plant operators	1271055	1260477	-0.83	2
25	Sales and services elementary occupations	2225239	2226487	0.06	17
26	Agricultural, fishery and related labourers	53599	53660	0.11	18
27	Labourers in mining, construction, manufacturing and transport	1274046	1272621	-0.11	9
28	All occupations	32464844	32464846	0.00	

Table 8. Wage Rates by Occupation, United Kingdom

Code	Occupation	(1) Wage Rate Growth 2009-20 (per cent per annum)	(2)	(3) Change in Wage Rate 2020	(4)
		Basecase	Mitigation	Per Cent	Rank
1	Armed Forces	-9.69	-9.79	-1.14	11
2	Legislators and senior officials	-7.59	-7.57	0.20	22
3	Corporate managers	2.80	2.78	-0.23	18
4	Managers of small enterprises	3.88	3.84	-0.40	16
5	Physical, mathematical and engineering science professionals	-0.05	0.00	0.59	23
6	Life science and health professionals	5.05	4.84	-2.17	6
7	Teaching professionals	-3.07	-2.98	1.06	25
8	Other professionals	4.55	4.42	-1.30	9
9	Physical and engineering science associate professionals	2.10	2.10	-0.03	19
10	Life science and health associate professionals	-0.26	-0.25	0.15	21
11	Teaching associate professionals	7.98	7.55	-4.28	2
12	Other associate professionals	8.52	8.07	-4.47	1
13	Office clerks	-0.36	-0.21	1.70	27
14	Customer services clerks	3.33	3.30	-0.36	17
15	Personal and protective services workers	3.78	3.71	-0.73	12
16	Models, salespersons and demonstrators	6.97	6.79	-1.85	8
17	Skilled agricultural and fishery workers	3.97	3.77	-2.13	7
18	Extraction and building trades workers	4.86	4.82	-0.48	15
19	Metal, machinery and related trades workers	-2.95	-2.90	0.61	24
20	Precision, handicraft, craft printing and related trades workers	-6.37	-6.27	1.16	26
21	Other craft and related trades workers	-1.10	-1.10	0.06	20
22	Stationary plant and related operators	4.46	4.34	-1.17	10
23	Machine operators and assemblers	4.08	3.84	-2.55	5
24	Drivers and mobile plant operators	6.58	6.20	-3.76	4
25	Sales and services elementary occupations	5.10	5.04	-0.56	14
26	Agricultural, fishery and related labourers	-5.19	-5.25	-0.65	13
27	Labourers in mining, construction, manufacturing and transport	8.50	8.08	-4.10	3
28	All occupations	4.14	4.14	0.00	

6. Concluding remarks

This paper has described an application of the MLME labour market extension to the E3ME macro-econometric model of the European economy. The general purpose of the extension is to elucidate structural pressures in the markets for labour that are implicit in the E3ME projections. Here, it has been used to show that such structural pressures may negate the efficacy of environmental policies that are driven by plausible notions concerning "green lobs".

The extension is based on CGE modelling techniques and its strength lies in its capacity to take into account available information on the structural linkages between industries, occupations and skills. It also involves parameters, such as elasticities of substitution and transformation, for which data is less readily available, and values for which must be imposed as a matter of judgment. However, the uncertainties associated with such judgements are likely to be minor when compared to the unspecified assumptions required to apply policy in an economy-wide context without the benefit of a formal model.

The particular policy initiative modelled in the paper involves the imposition of taxes on employment by industry. The purpose of the policy is just to redistribute employment from industries responsible for large amounts of pollution to industries responsible for smaller amounts. That is, its purpose is to facilitate an exercise in economic analysis and it is not being put forward for consideration as a practical way to reduce emissions. However, as it happens, a practical analysis of the appropriate kind has recently been undertaken by CEDEFOP (2013), based in part on new projections using the E3ME model. The present model would be well suited to investigate of the labour market implications of that study.

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