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# Modelling Strategy and Net Employment Effects of Renewable Energy and Energy Efficiency: A Meta-Regression

*Spyridon Stavropoulos*[1]
*Martijn J. Burger*[2]

[1] Erasmus Happiness Economics Research Organisation, Erasmus University Rotterdam
[2] Erasmus University Rotterdam

# Modelling Strategy and Net Employment Effects of Renewable Energy and Energy Efficiency: A Meta-Regression

Stavropoulos, S.[1*], Burger, M.J.[2]

**Abstract**

By conducting a meta-analysis of the empirical literature on the net employment effects of renewable energy, we explore the extent to which the reported net employment effects are driven by the applied methodology. We find that the reported conclusions on net employment effects are to a large extent driven by the methodology that is applied, where computable general equilibrium (CGE) and I/O methods that include induced effects and studies that consider only the near future in their study period (up to 2020) are generally less optimistic about net employment creation in the wake of the energy transition. In addition, we found that policy reports have a greater tendency to report a positive net employment effect than academic studies.

Keywords: renewable energy, net employment, meta-analysis, circular economy

[1*] Corresponding author: Spyridon Stavropoulos is researcher at the Erasmus Happiness Economics Research Organization, E-mail: stavropoulos@ese.eur.nl.

[2] Martijn Burger is associate professor at the Department of Applied Economics, Erasmus University, Rotterdam, Tinbergen Institute and academic director at the Erasmus Happiness Economics Research Organization, P.O. Box 1738, 3000 DR Rotterdam, the Netherlands. E-mail: mburger@ese.eur.nl.

## Introduction

Over the past few years, development of the circular economy (CE) has received increasing attention. The circularity of economic processes means that fewer unusable final components, products and energy remain at the end of production and consumption cycles, which minimizes both waste and pollution by saving on production inputs such as materials and energy ([1]; [2]). The Ellen MacArthur Foundation has distinguished four core strategies that can be used to move from a linear economy to a CE; these strategies are discussed throughout the whole CE literature ([3]) and are inherently linked to the R-frameworks or the 'how-to' frameworks of the CE ([4]; [5]). First, the prioritization of regenerative resources should ensure that renewable and reusable resources are efficiently utilized as energy and materials. Second, resource preservation through maintenance, repair and upgrades should maximize the lifetimes of resources. Third, the utilization of waste streams as secondary resources should result in the useful application of materials. Fourth, the sharing economy should stimulate more intensive product use and reuse.

Existing CE research and policy reports generally claim that it will result in economic prosperity, jobs, and improved well-being. For example, a recent report by WRAP (UK) [6,7] indicated that the CE could create 3 million extra jobs and reduce unemployment by 520,000 in EU member states by 2030 (also considering job offsets in other sectors). However, these conclusions are drawn under the assumption of significantly increasing recycling rates (by 34%) with substantial advancement in remanufacturing and servitization activities. In a more modest scenario outlined by WRAP, the number of jobs would increase by only 250,000 in the EU member states, reducing unemployment by 64,000 by 2030 ([6,7]). Jobs may be replaced, or job creation may be reduced by mechanization or automatization, which will make some occupations obsolete in the future ([8]). Overall, the potential economic effects of the rise of the CE as well as estimates on how many jobs will be lost are rather unclear.

The CE may have both a positive and negative effect on employment creation; this is not usually addressed in gross circular employment estimations. On the one hand, the CE creates new jobs in the energy, production, and services industries. On the other hand, the CE can also negatively impact the economy in two distinct ways. First, the CE can crowd out or substitute traditional sectors. For example, the rise of wind and solar energy will make coal fired power plants redundant. Second, additional consumption of circular products and services can reduce the budget for other expenditures, resulting in job losses in the targeted sectors. Both positive and negative impacts are multiplied and distributed through the economic system: increased employment increases expenditures for consumption (i.e., induced employment) and creates jobs in the respective sectors (as well as increases taxes). The negative effects of the CE work in a similar fashion. However, the potential job losses due to an increasing number of green jobs and enhanced technology are not considered in the gross employment estimates provided.

To obtain information on the net effects, one has to employ a model of the total (regional or national) economy. In economics, this is usually done through computational equilibrium modelling (CGE) or treatment effect (also known as impact analysis) models. In recent years, several papers have analysed how CE strategies affect the entire economy. In a recent report by Cambridge Econometrics, Trinomics, and ICF [9], the institutions forecasted that the CE would have a positive effect on employment (0.3%) in the EU. However, while some sectors (e.g., repair, recycling and waste management, and utilities) are expected to experience employment growth due to development of the CE, for other sectors (e.g., construction, consumer electronics, and motor vehicle construction), a loss in employment is expected. Likewise, some countries seem to profit more (e.g., Austria, Malta, the Netherlands, and Spain) than others (e.g., Croatia, Finland, Hungary, and Slovakia) from the rise of the CE. At the same time, an important limitation of the model used in the Cambridge Econometrics, Trinomics, and ICF report is that their results are largely contingent on the market uptake of circular activities, and no other comparison studies are available.

Although there is only limited information on the net employment effects of the CE as a whole and on recycling, refurbishment and other circular economy activities, there are now several studies on the net employment effects of renewable energy and energy efficiency. Here, we define renewable energy as "*energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat*" ([10]). Although renewable energy can replace employment in traditional energy sectors such as coal and gas, renewable energy generally is more labour-intensive for producing electricity than conventional fossil fuelled power plants. This is particularly true for solar and hydro power, while for wind power, biofuel and biomass, the net employment effects are typically smaller ([11]). Part of the renewable energy sector's labour intensity is driven by the belief that it is more domestically produced than fossil fuelled energy. Energy efficiency (e.g., thermal insulation of buildings) is also part of CE development since it reduces energy use. Energy efficiency measures are expected to have a positive effect on net employment effects because of their positive income effect: people can buy other goods and services because they spend less money on energy ([12]).

As shown in the recent research syntheses of UKERC [13] and Meyer and Sommer [11], studies that assess the net employment effects of renewable energy and energy efficiency generally report a small but positive net employment effect of such an energy transition. At the same time, the net employment effects vary greatly across studies (to the extent that the studies are comparable); therefore, renewable energy proponents and opponents can easily choose any study they like to support their point of view, while at the same time, the underlying reasons for these differences in outcomes remain unclear.

Although differences across studies can be attributed to their context (time frame, country, and elements of renewable energy), another possible reason for these differences is the methodology that is applied. There are currently three main methods used to examine the net employment effects of renewable energy and energy efficiency measures: CGE methods, input-output (I/O) methods, and the survey-based analytical method. As pointed out by Mu et al. [14], the three methods differ in their capability to estimate direct, indirect, and induced effects of renewable energy and a change in energy efficiency. Here, the direct employment effects are the jobs created due to the increased capacity of renewable energy, while indirect employment effects are related to the jobs that are created in the industries that support the expansion of the renewable energy sector. The overall impact of both the direct and indirect employment effects on net employment is considered to be positive.

In contrast, the induced effects can have either a positive or negative effect or, in some cases, a straightforward negative effect on overall employment. Induced effects can range from decreasing investments in fossil energy plants and changes in electricity prices to competition for capital, changes in labour wages, and changes in household income ([14]). In particular, the disappearance of conventional energy sources and competition for capital are expected to decrease net employment in the wake of the renewable energy transition through price increases. While all methods (CGE, I/O, and analytical) are capable of including direct and indirect effects, they vary in the degree to which they can include induced effects. CGE methods are capable of including all kinds of induced effects, while I/O methods can only address investment decreases in traditional energy sources and changes in household income. Analytical methods are not able to simulate any induced effects.

Because of measurement difficulties, the literature has paid less attention to induced impacts. Analytical methods, despite their inability to capture induced effects, are part and parcel of the CE net employment literature ([15]; [4]), particularly in influential policy reports drawn up by government organizations and charitable foundations. However, ignoring, even in part, the induced effects may make the energy transition's employment estimates too positive.

Building on the studies of UKERC [13] and Meyer and Sommer [11], the main purpose of this paper is not only to study whether going from fossil energy to renewable energy creates net employment effects but also why studies differ in terms of the reported effects. By providing a meta-analysis of the empirical literature on net employment effects of renewable energy, we explore the extent to which the reported net employment effects are driven by the applied methodology. The remainder of this paper is organized as follows. Section 2 provides an overview of the methodologies applied for meta-analyses. Section 3 provides our results, and Section 4 provides the discussion and concludes the paper.

## 2. Methodology

### 2.1 Search strategy

To acquire a systematic and representative set of journal articles, we used JSTOR, Science Direct, ISI Web of Science, and Google Scholar using the following set of keywords: 'renewable energy', 'net employment' or 'net jobs', and 'green growth'. We gathered academic studies and policy reports containing these keywords. Using the snowballing technique ([16]), we carefully scanned the references of all the journal articles, book chapters and agency reports that were obtained in our initial search to find other related studies. Subsequently, we reviewed all of the articles and included only those estimates that (a) reported net employment effects and (b) included sufficient information regarding their study design and empirical strategy. Several studies were excluded from our meta-analysis. First, as in this study, we only look at net employment effects; all studies reporting gross employment in the renewable energy sector were excluded. Second, studies that – in addition to renewable energy – also examined other circular sectors (such as recycling or repair) were excluded. Third, we excluded studies and reports written in a language other than English. In total, 30 journal articles and reports fulfilled our criteria to a sufficient degree. Table 1 provides information on the studies we included.[3]

[3] As a rule of thumb, 10 studies are considered enough for a meta-analysis [48]. In this study, we exceed this number and argue that the number of studies included in our paper is more than enough for conducting a meta-analysis.

**Table 1: Studies included in the meta-analysis**

| Study | Country | Type | Effect Found | Reference |
|---|---|---|---|---|
| Bach et al. (2002) | GER | Academic | Positive | [17] |
| Barrett et al. (2002) | USA | Policy Report | Positive | [18] |
| Bezdek et al. (2005) | USA | Academic | Positive | [19] |
| Blazejczak (2014) | GER | Academic | Positive | [20] |
| BMU (2006) | GER | Policy Report | Positive | [21] |
| Böhringer et al. (2013) | GER | Academic | Mixed | [22] |
| Bouzaher et al. (2015) | TUR | Academic | Positive | [23] |
| Cai et al. (2011) | CHN | Academic | Mixed | [24] |
| Chateau et al. (2013) | OECD | Academic | Negative | [25] |
| Climate Institute (2009) | AUS | Policy Report | Positive | [26] |
| EU (2014) | EU | Policy Report | Positive | [27] |
| Henriques et al. (2016) | POR | Academic | Mixed | [28] |
| Heindl & S. Voigt (2012) | GER | Academic | Mixed | [29] |
| Hillebrand et al. (2006) | GER | Academic | Mixed | [30] |
| ILO (2009) | Global | Policy Report | Positive | [31] |
| IDC (2011) | ZA | Policy Report | Positive | [32] |
| Kammen et al. (2004) | USA | Policy Report | Positive | [33] |
| Lehr et al. (2012) | GER | Academic | Positive | [34] |
| Lund et al. (2012) | DEN | Academic | Positive | [35] |
| Markandya et al. (2016) | EU | Academic | Positive | [36] |
| Moreno et al. (2008) | ESP | Academic | Positive | [37] |
| Moscovitch (1994) | USA | Academic | Negative | [38] |
| Neuwahl et al. (2008) | EU | Academic | Mixed | [39] |
| Peltier (2017) | USA | Academic | Positive | [40] |
| PERI (2009) | USA | Policy Report | Positive | [41] |
| Scott et al. (2008) | USA | Academic | Positive | [42] |
| Wei et al. (2010) | USA | Academic | Positive | [43] |
| Whiteley et al. (1999) | EU | Policy Report | Positive | [44] |
| WW Fund for Nature (2001) | USA | Policy Report | Positive | [45] |
| Ziegelmann et al. (2000) | GER | Academic | Positive | [46] |

## 2.2. Dataset used for the meta-regression

In this section, we present some data from the studies included in our analysis, presented in Table 2. The majority of the studies we examined were published after 2000; only 4 were published before 2000, indicating that the relationship between net employment effects and RES has received particular attention in recent decades. Nevertheless, most studies focus on the near future, as evidenced by the fact that studies that examine net employment effects up to 2020 are more common than studies that examine net employment effects in the more distant future.

In terms of which renewable energy sectors are scrutinized, most studies examine the net employment effects of the renewable energy sector as a whole, while some focus on specific RES sectors, such as wind energy, biofuels and energy efficiency. In terms of the methodology applied, 18 studies used an I/O analysis, 7 studies used CGE analysis, and 5 studies used analytical methods. Of these, 11 examined only the direct effects of net employment on RES and 19 studied the direct, indirect and induced effects. Geographically, studies were conducted on the United States (9 studies) and Germany (8 studies). We found 7 studies that covered other countries, and 6 studies covered a group of countries other than Germany and the United States. The majority of the studies were published in peer-reviewed academic journals (20 studies), and 10 studies were published as reports from consultancies, charitable organizations and/or governments.

**Table 2: Descriptive statistics of the variables**

| | Number of Studies | Positive (%) | Negative or Mixed (%) |
|---|---|---|---|
| CGE | 7 | 4 (57%) | 3 (43%) |
| I/O | 18 | 13 (72%) | 5 (27%) |
| Analytical methods | 5 | 5 (100%) | 0 (0%) |
| | | | |
| Direct and/or Indirect Only | 11 | 11 (100%) | 0 (0%) |
| Direct, Indirect and Induced | 19 | 11 (58%) | 8 (42%) |
| | | | |
| Short-Term | 18 | 11 (61%) | 7 (39%) |
| Long-Term | 12 | 11 (92%) | 1 (8%) |
| | | | |
| Energy Efficiency | 4 | 3 (75%) | 1 (25%) |
| Renewable Energy | 23 | 17 (74%) | 6 (26%) |
| Renewable Energy (Part) | 3 | 2 (67%) | 1 (33%) |
| | | | |
| Germany | 8 | 5 (62%) | 3 (38%) |
| United States | 9 | 8 (89%) | 1 (11%) |
| Other countries | 7 | 5 (71%) | 2 (29%) |
| Country groups | 6 | 4 (67%) | 2 (33%) |
| | | | |
| Academic Study | 20 | 12 (60%) | 8 (40%) |
| Policy Report | 10 | 10 (100%) | 0 (0%) |
| | | | |
| All | 30 | 22 (73%) | 8 (27%) |

Table 2 shows the findings by the applied methodology and study focus. Of the 30 studies included in our literature review, 22 reported only positive net employment effects, while 8 reported mixed positive and negative effects or negative net employment effects. In line with our expectations, the studies using analytical methods only focused on the direct and indirect effects, and policy reports have a greater tendency to report positive effects. This will be further explored in the next section.

### 2.3 Meta-regression model

Due to the nature of the dependent variable, we use a linear probability model, which has been used to estimate dichotomous choice models. This model works as a linear regression model, but differs because the interpretation changes with a binary dependent variable.

$$\hat{P}(y = 1|x) = \hat{y} = \hat{b}_0 + \hat{b}_1 x_1 + \cdots + \hat{b}_k x_k$$

where $\hat{y}$ is the predicted probability of $y = 1$ for the given values of $x_1 \ldots x_k$

The linear probability model has been criticized by some scholars because of heteroscedasticity and the possibility of predicting probability outside the 0-1 interval. The heteroscedasticity can be fixed by using robust standard errors. Moreover, in our study, the predicted probability lies inside the unit interval, so our main estimate is unbiased and consistent. In our case, the advantage of using a linear probability model over a logit or probit model is that some parameters of importance can be estimated. In particular, our model contains dummy variables that indicate whether the study uses analytical models and whether the study is a peer-reviewed academic study. Since studies that belong to both groups solely report positive net employment effects, logit or probit models are not able to estimate a coefficient of these group dummy variables. This is, however, possible with a linear probability model. For a detailed discussion of the advantages of using the linear probability model over logit or probit models, please refer to Caudill [47].

## 3. Results

Table 3 shows estimates of the linear probability model on the probability that a study will only report positive net employment effects. Our full model explains 55% of the variation in the reported effects. In Model 1, only the modelling strategy is included in our estimation. We find that studies using a survey-based analytical method are more likely to report larger net employment effects. Compared to using CGE models (which can incorporate all kinds of induced effects), using analytical methods increases the probability of reporting a positive effect by 43%. The difference between the CGE and I/O methods is statistically not significant. However, these effects seem to be predominantly driven by the inclusion of induced effects. Model 2 includes the examined effects and a time period. The results indicate that studies considering only direct/indirect effects but excluding induced effects report larger net employment effects. Including the induced effects reduces the probability by almost 50% that the study will report a positive effect, controlling for the time frame and methodology. Furthermore, in studies where the period extends beyond 2020, the reported net effects are larger. Studies that examine the more distant future have a 38% greater probability of reporting a positive net employment effect. These findings hold when controlling for geography and type of study (Models 3 and 4). For Models 3 and 4, our results also support our scepticism regarding the magnitude of effects that non-academic (i.e., non-peer reviewed) papers find. In line with the descriptive statistics, policy reports have a 30% greater probability of reporting a positive net employment effect, even when controlling for methodology and included effects. Hence, the fact that the policy reports have a greater tendency to report positive net employment effects cannot be attributed only to their more intensive use of analytical versus CGE and I/O methods or the non-inclusion of induced effects but also to other (unexplored) factors. These unexplored factors include the fact that there is a positive reporting bias to support further development of the CE. This finding is of importance, as policy makers, organizations and institutions develop policy based on the results of these reports. By realizing that there is a potential bias in the estimation of the reported net employment effects, policymakers need to consider different or additional information to make better strategic decisions.

Table 3: Results of the linear probability model

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| ***Modelling Strategy*** | | | | |
| CGE | Reference | Reference | Reference | Reference |
| I/O | 0.15 (0.23) | 0.27 (0.20) | 0.06 (0.27) | 0.20 (0.21) |
| Analytical methods | 0.43 (0.20)* | 0.16 (0.16) | 0.24 (0.31) | -0.08 (0.25) |
| ***Examined Effects*** | | | | |
| Excluding Induced Effects | | Reference | | Reference |
| Including Induced Effects | | -0.47 (0.12)** | | -0.51 (0.14)** |
| ***Period*** | | | | |
| Short-Term | | Reference | | Reference |
| Long-Term | | 0.38 (0.13)** | | 0.39 (0.14)* |
| ***Focus*** | | | | |
| Renewable Energy | | | Reference | Reference |
| Renewable Energy (Part) | | | -0.07 (0.30) | -0.12 (0.22) |
| Energy Efficiency | | | 0.21 (0.20) | 0.06 (0.26) |
| ***Area*** | | | | |
| United States | | | Reference | Reference |
| Germany | | | 0.02 (0.27) | -0.05 (0.27) |
| Other countries | | | -0.03 (0.21) | -0.14 (0.24) |
| Country groups | | | -0.10 (0.27) | -0.31 (0.24) |
| ***Type of Study*** | | | | |
| Academic Study | | | Reference | Reference |
| Research Report | | | 0.42 (0.16)* | 0.30 (0.15)# |
| | | | | |
| Number of Observations | 30 | 30 | 30 | 30 |
| R-Squared | 0.09 | 0.40 | 0.25 | 0.55 |
| Robust standard errors in parentheses; **p<0.01, *p<0.05; #p<0.10 | | | | |

## 4. Concluding remarks

Over the past few years, numerous studies have examined the net employment effects of renewable energy. Although the majority of them conclude that the net employment effects will be positive, some studies are less optimistic about net employment creation, and the outcomes seem to depend very much on the methodology. The estimations that include induced effects are generally less optimistic about net employment creation in the wake of the energy transition. Partly because policy reports tend to use methodologies that do not include induced effects, they generally report more positively about net employment creation related to renewable energy than do academic studies. Where the direct and indirect employment effects are generally positive, the induced effects can be either positive or negative ([14]). Specifically, the disappearance of conventional energy sources and competition for capital are expected to decrease net employment, while the effects of changes in electricity prices, labour wages and household income are uncertain.

As only a limited number of studies include induced effects, the current literature is perhaps too enthusiastic about the net employment effects of renewable energy and energy efficiency, and future studies and policy reports need to take into account the induced effects. This is also important when examining other parts of the CE, such as recycling and the sharing economy. Currently, the literature has not considered all of these aspects, but such an analysis is very much needed to inform the public and policymakers about the consequences of making the economy more circular. At the same time, our study shows that policymakers have to be cautious when drawing conclusions regarding net employment creation based on a single study. Deception is possible since the presented results may be sensitive to model specification, and studies may not consider all potential effects of a transition. More attention to the particularities of the studies is therefore also warranted in the policy arena.

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