Economic theories and methodologies to assess the impact of climate change on employment
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Abstract

This paper is part of a series of discussion papers that have been prepared by the International Institute for Labour Studies (IILS) within the framework of the joint project “Addressing European labour market and social challenges for a sustainable globalization”, which has been carried out by the European Commission (EC) and the International Labour Organization (ILO). The discussion paper series provides background information and in-depth analysis for two concluding synthesis reports that summarize the main findings of the project. This paper relates to second part of the project “Preparing European labour markets to adapt to the long-run challenge of ensuring the joint social and environmental sustainability of globalization” and the concluding synthesis report “Towards a Greener Economy: The Social Dimensions”. An essential aspect of this discussion paper is to present economic theories and methodologies to assess the impact of climate change on employment for the purposes of the joint EC-ILO study. The paper focuses on both empirical analysis and theoretical models by describing input-output (IO) models, Social accounting matrix (SAM), growth and real business cycles (RBC) models, computable general equilibrium (CGE) models and econometric models.
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Main findings

• The diversity of models presented here highlights the difficulties in analyzing the structural change to a low-carbon-intensive economy. The implications of such a structural change, given its complexity and inter-related nature, are not easily captured by any one model. The solution appears to be a diversified approach in which different models are employed to address different issues.

• Input-output (IO) models are the best available option to answer questions about changing industry structures. This is because IO models contain disaggregated industry structure data that can adequately map transitions of output and employment among industries with the necessary accuracy. Furthermore, they are built primarily to be applied to empirical data. IO tables can be considered as a special case of a social accounting matrix (SAM), which is a technique to present the results of national accounting in a matrix form. SAM’s allow for an extended analysis of socioeconomic impacts.

• Purely theoretical models can be useful where empirical analysis is impossible or empirical results need to be interpreted. In this respect, models of this nature can shed light on the main thought concepts and to identify possible cause-and-effect chains. For instance:
  ○ Growth and real business cycles (RBC) models are both useful, in particular if macroeconomic variables such as aggregate output, aggregate
employment or inflation are of interest. However, limitations of these models with respect to addressing labour market questions should be kept in mind.

- Economists generally study the economics of climate change from the perspective of economic growth theory (e.g. Nordhaus (2008)), since the theory is concerned with long-term development. Growth models can be used to analyze the question of a double dividend (i.e. positive effects on employment and the environment through an adequate policy) with GDP growth serving as a rough proxy for welfare.

- Historically, computable general equilibrium (CGE) models were built upon IO models and/or SAM’s, as e.g. in Johansen (1960), but CGE models differ from IO models because they add specifications of behavioural assumptions and availability of markets. Usually, CGE’s are multisector models that consider about 5 to 50 production sectors and at least one household sector. Assumptions of CGE models are often in line with the neoclassic school of thought.

- Econometric models are well suited and the only way to find empirical evidence on the double dividend hypothesis. The ILO (2009) identified three major studies that have used econometric models to analyze the double dividend of green policies. In all three models, a reduction in CO₂ emissions via tax instruments conveys positive effects on employment, even when tax revenue is not recycled.

A. Modelling approaches for analyzing sustainability and employment

Studying sectoral adjustment processes in relation to aggregate output growth is a complicated task, and taking into account the impacts on the labour market imposes additional difficulties. The challenge is to find an appropriate modelling framework that is simple enough to understand major cause-effect relationships between climate change and employment, but also rich enough to reveal more than obvious insights. In this discussion paper, several economic modelling methodologies are discussed along with their caveats and advantages.

Economic models attempting to describe the relationship between climate change and employment should ideally also be capable to allow for an assessment of climate change measures (e.g. carbon tax) on employment. If not only the effects of climate change itself but also the effects of climate policies are taken into account, one essentially deals with the
“double dividend” concept. This double dividend – a central theme for policy makers and academics – can be realized if a policy mix not only results in the benefits of improved environmental quality but also achieves other policy goals. In labour market terms, the second dividend is primarily a possible increase in employment. For example, a carbon tax would generate government revenue that could be used to reduce labour taxes, which would in turn stimulate labour demand. If the outcome of this policy is an increase in environmental quality, e.g. a reduction of global greenhouse gas emissions, and the policy leads at the same time to an increase in employment, one would have realized a “double dividend”.

Many studies have used economic models to study the interdependencies of climate change, climate policies and employment. The following section examines the major modelling approaches.

B. Growth models

Economists generally study the economics of climate change from the perspective of economic growth theory (e.g. Nordhaus (2008)), a seemingly obvious choice since the theory is concerned with long-term development. Growth models – whether neoclassical or heterodox – typically only consider aggregate output growth and disregard questions of a changing output and employment structure.

Standard (exogenous) growth models, usually based on the work of Ramsey (1928), Cass (1965) and Koopmans (1965), follow the neoclassical school of thought: a representative household optimizes consumption over time and a representative firm maximizes the present value of profits. If certain technical conditions are met, an “optimal” (i.e. Pareto efficient) growth path can be reached. The restrictions these models impose on certain economic parameters are quite strong. Besides neoclassical assumptions concerning the production function, technological change is exogenous and a Walrasian labour market ensures that involuntary unemployment cannot occur.

A detailed discussion of neoclassical growth models can be found in Barro and Sala-i-Martin (2004) or Aghion and Howitt (1998). Other types of growth models are more aligned with the Keynesian tradition (see Palley (1996a), (1996b); Taylor (1983)), but their interest also primarily remains aggregate output growth. General discussions of economic growth are provided by Taylor (2004) or Foley and Michl (1999).

Endogenous growth models as promoted by Romer ((1986), (1990)) or Aghion and Howitt (1992) allow for endogenous technological change. Some extensions of aggregate output models consider two sectors (see Uzawa (1964), (1965); Rebelo, (1991)). A limited number of approaches deal with the question of growth and unemployment (e.g. Aghion and Howitt (1994)); growth models that also study the interrelation between economic growth and the environment can be found in Greiner and Semmler (2008). The authors
cover a wide range of models with environmental features ranging from pollution, renewable and non-renewable resources to problems of temperature rise due to climate change.

Economic growth models are technically advanced and allow a wide range of environmental issues to be studied, including climate change impacts and the effects of associated policies. However, most models are constructed in the neoclassical tradition and the restrictive assumptions concerning production structure and market clearing processes are often not supported by empirical data (see Foley and Michl (1999)). A further problem with all growth models is that structural change – particularly multi-sectoral analysis, reallocation of labour among sectors and involuntary unemployment – is typically neglected, in part or total.

A neoclassical growth model that allows for a reallocation of employment and output between two sectors has been developed by Kongsamut, Rebelo, and Xie (2001). This model has been used by Mittnik, Semmler, Kato and Samaan (2010) as the basis for a model that specifically shifts employment and output shares over time from a high-carbon sector to a low-carbon sector.

Growth models can be used to analyze the question of a double dividend, with GDP growth serving as a rough proxy for welfare. Growth models need to either take labour markets specifically into account or at least allow for tax effects on labour market outcomes. Many growth models work with a full employment assumption or disregard involuntary unemployment. In these cases, several questions regarding the second dividend of higher employment (lower unemployment) cannot be addressed.

C. Input-output models

Input-output (IO) analysis was developed by Wassily Leontief (1936), and has since become one of the most popular modelling methods in economics. Most countries with advanced national accounting systems provide IO tables, which exist both as theoretical modelling frameworks and as empirical data bases. The main purpose of IO analysis is to analyze the interdependence of industries in the economy (see Miller and Blair (2009)). IO tables provide a snapshot of the current production and consumption structure of an economy.

In general, it is useful to test economic models with available empirical data, or at the very least apply them to empirical observations. In the case of IO models, the affinity between theory and empirical data is strong. The main variables of IO models are the input and output values of individual industries or sectors. These data are provided in a matrix format that allows for studying the IO relations among the economic sectors for a particular year. Furthermore, the use of final output for consumption, investment or export or by government is included for each industry. It is therefore possible to
determine which industry is engaged in which stage\textsuperscript{1} of the production process – for example, whether mainly intermediate inputs or final goods are produced, and whether private households, foreign customers, the government or private firms are consumers of the output.

Often it is assumed that the observed IO coefficients, i.e. the ratios between inputs and outputs of each industry with every other industry, are constant. At least in the short run, such a simplifying assumption is justified. Under these circumstances, the impact of changes in exogenous final demand on the whole production structure of the economy can be examined. IO models exist in the form of physical flows and monetary flows. In national accounting systems, data is predominantly found in terms of monetary values, although the applicability of IO models is not restricted to monetary variables.

IO analysis is very well suited to analyzing questions of structural change. Of all economic modelling approaches discussed here, IO provides the most detail with regard to industry heterogeneity. The methodology furthermore allows for a high degree of flexibility, and many extensions of the basic model exist. For example, IO models have studied international trade patterns as well as ecological impacts.

Particularly relevant in the context of climate change are energy IO models, which trace energy flows in the economy, and environmental IO models, which account for inputs from and outputs to the environment. The impacts of new energy technologies on the economy have been studied with the help of IO models since the late 1960s, as for example in Gowdy and Miller (1968), Herendeen and Plant (1981), Casler and Hannon (1989) and others. Their impacts have been analyzed within an IO framework by Herendeen (1974) and Bullard and Herendeen (1975). (Refer to Miller and Blair (2009) for a comprehensive survey of IO methods.)

There exist also a number of problems with IO analysis, both theoretical and empirical. Theoretically, the model is linear and coefficients are assumed to be constant over time. Thus technological change – an essential element of structural change – is not taken into account. Furthermore, possible behavioural responses to a change in relative factor prices are not considered. And while industry-specific labour demand could easily be included in the analysis, the linearity of the standard model prevents the study of complex labour market mechanisms that, for example, allow for productivity increases or economies of scale.

IO models are only a partial analysis, since solely the impact of changes in exogenous demand on the production structure of the economy is considered. Thus, the models can analyze the consequences of exogenous change, but cannot explain the actual changes in exogenous demand. The supply of the economy is assumed to be fully elastic and feedbacks on demand, for example through increases in income in certain sectors, are

\textsuperscript{1} not in a temporal sense
typically neglected. Long run analysis is complicated by the fact that the linearity assumption is likely to be violated and that coefficient values do change over time. Results and predictions for longer time periods, therefore, become increasingly inaccurate.

Several of these theoretical problems can be addressed through extensions to the baseline model, which are abundant and allow for changing coefficients (see for example the survey by Allen and Grossling (1975) on the RAS technique), dynamic analyses, or structural decomposition analysis (SDA). The roles of labour, households and social institutions can be included by combining IO models with a social accounting matrix (SAM). In general, IO models are easily combined with other models, such as computable general equilibrium (CGE) models and macro models.

The problems associated with IO become more severe when they are not only used as a theoretical tool but also incorporate empirical data. As stated, IO models provide a high level of detail about the economy at one point in time and are well-suited to work with empirical data. However, since the data collection efforts are very high, not all countries provide IO tables. If IO tables are produced by countries' statistical offices, they are often not comparable with other countries' tables since the levels of industry aggregation may differ. Often, tables are incomparable over time due to changes in types of industry or changes in the availability of data about these industries.

Some countries prepare IO tables only for longer cycles (e.g. every 5 years). The resulting lack of data and small sample sizes may restrict the applicability of statistical methods in this context. This problem should not be underestimated. Data on aggregate output growth rates, which may be useful for empirical applications of growth models, are usually available for several decades. And for many industrialized countries, aggregate output data are even available on a quarterly or monthly basis. Time series in these cases may contain between 50 to 250 data points. IO tables, however, may only contain samples of about 10 data points or less due to their longer cycles, severely limiting the statistical conclusions that may be drawn.

An important aspect in understanding employment effects of climate policies is the interdependency between industries that produce technology for climate mitigation (e.g. the renewable energy industry) and the rest of the economy. The impacts of a promoted expansion of these industries, in terms of direct and indirect employment, could be studied with IO data. For this purpose, the IO tables would have to be disaggregated so that certain ("green") industries that produce climate mitigation technology are treated as separate categories. For example, an IO table with a category for the “renewable energy sector” would allow a researcher to study the effects of the renewable energy sector on the rest of the economy or to observe employment shifts within the energy sector. Unfortunately, no country produces such IO tables at this time. Common IO tables do not include a separate category, like "renewable energy sector", but instead report on the energy sector as a whole.
Study of the employment impacts of a transition towards a low-carbon economy is further limited by the amount of employment data available. Since IO tables usually do not include employment, the data must be obtained from other sources and are usually not compatible with the given structure of the IO tables. If employment data are available, IO analysis can be used to determine direct and indirect employment effects of a change in exogenous demand that could be caused by a policy shock, for example. Since the basic IO model is a partial analysis, no specific labour market or labour supply models exist. As supply is assumed to be fully elastic at given labour market and wage conditions, exogenous demand shocks are directly translated into quantitative changes in employment.

Finally, in order to conduct an in-depth analysis, data on the climate impacts of individual industries are needed in addition to data on industries that produce environmentally related technologies. The most relevant impact that industries and households have on climate change is their emissions of greenhouse gas (GHG), measured in CO₂ equivalents. Thus, industry-specific data on CO₂ emissions are required. No data on CO₂ emissions are reported in IO tables, and alternative data sources for emissions are rarely compatible with the structure of IO tables. Nevertheless, an approach introduced by Proops et al. (1993) indicates that CO₂ emission data can be combined with IO tables and employment data in order to perform an empirical analysis of employment effects.

IO analysis is not well suited to analyzing the double dividend question in the narrow sense. While it is possible to study employment effects and sectoral transitions induced by climate change policies, the effects of tax policies on welfare cannot easily be studied. The common literature on welfare economics and tax incidence refers to behavioural changes caused by taxes and corresponding utility losses. But IO models generally do not employ any behavioural model.

D. Social accounting matrix

A Social Accounting Matrix (SAM) is a technique which presents the results of national accounting in a form of a matrix (see Stone (1949), (1951-52), (1955a), (1955b), (1961)). IO tables can be considered a special case of a SAM. As discussed in the previous section, an IO table is a statement in current money terms on the flow of goods and non-factor services between the operating accounts of the system and between these and all other accounts combined (Stone (1955b), Stahmer (2002)).

Stone (1962b) improves the conceptual framework of SAM’s in the publication of a first SAM for Great Britain 1960 (see Stahmer (2002)). He emphasizes the importance of using different statistical units such as commodities, establishments and institutional units, in the system for describing the variety of economic activities in a most appropriate way. In this sense, as shown by the System of National Accounts (SNA) 1968, different parts of the accounting system are linked by special transition matrices from one statistical unit to another (see United Nations (1968), Stone (1962a)). Therefore, the supply and disposition
tables of the IO framework become a main basis of the national accounting matrix (United Nations (1968), Stone (1979), (1981b)).

Since the 1970s, the concept of SAMs has been successfully used for describing and analyzing the interrelationships of income and transfer flows between different institutional units. As socio-economic analysis has become an integral part of the revised concepts of national accounting, SNA 1993 as well as ESA 1995 contain chapters on SAM which demonstrate its importance and the great variety of its applications (see Commission of the European Communities et al. (1993), Eurostat (1995)). As Stahmer (2002) points out, the ESA describes different types of matrix presentation of national accounts data and an IO table is a well-known example of such a presentation.

In the presentation of full sequence of ESA accounts and balancing items in a matrix format, each entry in an aggregate matrix can be seen as a grand total of a submatrix, which shows detailed information by different types of transactors or other groupings. The SAM is a special type of matrix presentation which allows a further elaboration on the interrelations between the social and economic aspects of the system. Therefore, the SAM is a presentation of ESA-accounts in a matrix format which elaborates on the linkages between a supply and use table and sector accounts. Due to further breakdowns of household sector and the persons employed, two parts of the use table of the IO framework are especially disaggregated: the components of net value added and the final uses.

A detailed matrix of net value added, which is presented by the ESA, recommends further disaggregation of compensation of employees, net operating surplus, employees, and labour income. In the IO framework, final uses are subdivided by product group (see Stahmer (2002)).

SAM presents interdependence between variety of economic sectors and industries, and also provides information about employment, capital, households and other socio-economic groups. It is possible to examine employment in different sectors that are presented in the SAM.

SAM is often used with environment accounts (SAMEA), where economic accounts are expressed in monetary units and environment accounts are shown in physical units. This combined matrix is an essential foundation of a multisectorial model of economic and environmental performance. SAMEA includes economic flows related to the production activity and consumption. From an environmental perspective, SAMEA also contains the environmental inputs consumed as resources (reading by rows) as well as emissions and discharged pollutants to nature (reading by columns) (Morilla et al. (2006)). SAM based modelling allows therefore for an analysis of interdependencies between the environment and different socio-economic groups or institutions. Comparable to IO analysis, SAM based models can map the structure of the economy and are suited to analyze questions of distribution or changing industry structure. SAM’s by itself are in the first step just accounting tools and not models per se. The SAM can, however, be used for supply-side
models, as many current CGE models are, or they can be applied to perform Keynesian type, demand driven analyses.

E. Computable general equilibrium models

Historically, CGE models were built upon IO models, as e.g. in Johansen (1960), but have little in common with the type of IO models discussed in the previous section. CGE models differ from IO models because they add specifications of behavioural assumptions and availability of markets. As CGE models stresses the multi-sectoral and multi-class breakdowns, these models are based on the socio-economic structure of a SAM. While no precise definition of CGE models exists, they do tend to have common features (see Bergmann (2005)).

Usually, CGE's are multisector models that consider about 5 to 50 production sectors and at least one household sector. Production functions exhibit constant returns to scale. The assumptions of CGE models are often in line with the neoclassic school of thought. Thus, markets are assumed to operate in a Walrasian manner with flexible prices and market clearing. Producers maximize profits and households maximize a homothetic utility function. While it often claimed that parameters for the equations are usually based on available real world data, there exists also a lack of transparency as to how parameter estimations are actually determined. In addition to empirically estimated parameters and neoclassical assumptions, CGE's often make several ad-hoc assumptions in order for the model to be solvable (see Bergmann (2005)).

General equilibrium theory in the sense of Walras (1874) and Debreu (1959) is static, as were the first CGE's. Most CGEs are still static in current day, although dynamic CGE's do exist. It is important to carefully consider what exactly is meant by “dynamic”. Bergmann (2005) provides an overview of several CGE's recently applied to environmental questions. He makes a distinction among "static", "quasi-dynamic" and "fully dynamic" models. Given the increased computing powers obtained in the last decades, models increasingly apply dynamic optimization techniques to arrive at solutions.

It is not appropriate to think of CGE in the sense of the equilibrium theory of Walras and Debreu, whose efforts aimed to show that a price vector exists such that for all goods and markets excess supply equals zero, if certain exogenously determined assumptions are satisfied. CGE modelling is an attempt to use general equilibrium theory as an operational tool in empirically-oriented analysis of resource allocation and income distribution issues in market economies (see Bergmann (2005)). Thus, the general equilibrium approach is applied in an entirely different economic environment than that of Walras and Debreu. The application of ”general equilibrium theory” can only be understood as an approach of solving simultaneous (economic) equations systems. As Mitra-Kahn (2008) points out, CGE's are not micro models, but rather macro models that are based on macroeconomic
accounting identities usually delivered through a SAM. He suggests the term "computable macro equilibrium models".

The usefulness of CGEs in policy evaluation is often questioned since transparency in CGE’s is not always ensured. The strong behavioural assumptions of CGEs and concerns over the validity of closing the models further thwart policy analysis with CGEs. Nevertheless, CGE's are widely used in the study of the economics of climate change. Examples include the GREEN model of OECD and the Emissions Predictions and Policy Analysis (EPPA) model of MIT. In most of these models, emphasis is placed on the impact of different policy scenarios on the stock of emissions, carbon leakage, GDP growth, international trade effects, and environmental quality, which is sometimes measured as public health.

Labour market questions are usually not considered, since the models are not well suited to incorporate labour market issues, such as the structural conditions of employment. While CGE modelling is already a challenging task for general economic questions, its complexity increases significantly if environmental problems are added (see Bergmann (2005)). And an appropriate consideration of labour market effects complicates the analysis even further. A CGE model which considers employment effects of climate policies has been proposed by Babiker and Eckaus (2007). It is an extension of the EPPA model. The authors also discuss some of the challenges of modelling labour market issues in a CGE framework.

Several CGE models attempt to find evidence of the "double dividend". Due to the incorporated behavioural model, CGE's are better suited to make statements about welfare effects than IO models. However, CGE models are inconclusive on the existence of the “double dividend”. For example, Bovenberg and Goulder (1994), Goulder (1995), and Goulder, Parry, and Burtraw (1997) find little or no evidence, while Jorgenson and Wilcoxen (1993) and Bye (2000) do find evidence.

F. Real business cycle models and New Keynesian approaches

Real business cycle (RBC) models in the tradition of Kydland and Prescott (1982) have been a main pillar of macroeconomic theory for the last 30 years. RBC models fall under the neoclassical tradition, assuming complete and perfect markets, and have a great technical affinity with optimal growth models. Essentially, RBC formulations are Ramsey models with an added technological error term (see Taylor (2004)). RBC models do have limitations that stem from the difficulties in applying neoclassical growth theory to the study of structural change and employment effects. RBC models consider a very limited structure of the economy and its institutions and focus on aggregate variables. In addition, RBC models usually make the assumption of full employment or work with a rudimentary
model of the labour market. A rich analysis of employment effects is, therefore, constrained with RBC models.

In contrast to the long time horizon of growth models, RBC models focus on the short term and consider fluctuations of the economy. The models can therefore be useful in studying the short-term effects of policy shocks. It should be noted that standard RBC models consider fluctuations in aggregate output to be the outcome of rational decisions made by economic agents, combined with random, unpredictable technology shocks. In this sense, these fluctuations are not seen as deviation from some kind of trend or equilibrium. The real economic outcome as seen from the perspective of an RBC model, including any fluctuations, is therefore Pareto optimal with little room for welfare-improving policy interventions. For a more detailed discussion of RBC models, refer to Snowdon and Vane (2005).

New Keynesian models attempt to include market imperfections and sticky prices into RBC type models. A variety of New Keynesian approaches exist, as surveyed by Mankiw and Romer, for example. Bridji & Charpe (2011a) develop a New Keynesian model that includes goods and labour market frictions (see also Bridji & Charpe (2011b)). This model is designed to deal with questions of fiscal policy and labour market segmentation.

Few RBC models exist that account for climate change or the environment. Heutel (2008) attempts to determine the optimal environmental policy in response to economic fluctuations, but he specifically excludes the labour market from his analysis. He finds that the optimal emissions tax rate and the optimal emissions quota are both procyclical: during recessions, the tax rate and the emissions quota both decrease. Fischer and Springborn (2009) study the impacts of different climate policies on productivity shocks in the economy. In particular, they study the effects of an emissions tax, a cap and intensity targets on the levels of labour, capital, and output. As is the case in most RBC models, the labour market characteristics are only rudimentarily considered.

No RBC or New Keynesian models exist so far that are designed to analyze the employment effects of climate change or climate change policies. Therefore, no studies yet exist that attempt to analyze the issue of the double dividend. In principal, it is however possible to address the question of a double dividend in an RBC (New Keynesian) framework.
**G. Econometric models**

In this discussion paper, econometric models include all kinds of economic models that are mainly based on observed data and employ statistical methods. Strictly speaking, "econometric models" cannot be distinguished from other models discussed in this paper, since any theoretical model (or at least the implications of the theory) should be empirically tested with the help of statistical methods. This paper refers only to those econometric models that put the greater emphasis on correlations of actually observed data than on theoretical economic relationships.

In a time series approach, little economic theory is imposed on the model a priori. Instead, the main idea is to assume that past and current observations of data contain information about future values of variables of interest. Basically, these models assume that some kind of stable relationship or pattern can be found in past data that also prevails in the future.

Technically, actual observations are treated as the realizations of a stochastic process whose basic structure is usually a white noise process that is often assumed to be normally distributed. Based on this white noise process more complex stochastic processes like autoregressive processes (AR), moving average processes (MA) or combinations thereof (ARMA) can be constructed. The important aspect of this approach is that the characteristics of the processes are determined by statistical properties and not by economic features.

Past experience showed that parsimonious models atheoretic models often outperform complicated large models with many parameters when it comes to forecasting (see for example Ashley (1988), Nelson (1972). Based on this insight, Box-Jenkins (1976) advocated the so called Box-Jenkins methodology, in which forecasts are based on the application of ARMA models to past data. When little is known in terms of theory, this approach appears particularly promising and allows researchers to find correlations among data. The main difference between econometric models and the other methodologies is that very little economic theory is required to make forecasts. Further discussion can be found in standard references like e.g. Lütkepohl (2005) or Hamilton (1994).

The limitations of econometric approaches are often statistical in nature and frequently concern the data. Problems with data are characterized by missing observations, short samples or non-availability of data. If not enough data points can be found, the estimation of parameters might be limited or impossible. The same applies to the statistical significance of estimated parameters (This discussion paper is confined to parametric statistical methods). In time series econometrics, where researchers rely largely on field data, small sample sizes are particularly challenging since there is no way to find or create missing data. Furthermore, assumptions have to be made about the idealized, underlying mathematical process, e.g. regarding its distribution or its ergodicity. These assumptions may be more or less appropriate in different cases.
Another problem stems from the assumption that the observed data are derived from a data–generating, stochastic process. Thus, even if certain patterns in the data can be revealed or accurate forecasts can be made, the "true" mechanisms or economic causes remain unknown. This makes it difficult to offer explanations of any observations in terms of economic theory. The fact that theory is not heavily imposed on econometric models does indeed offer advantages, but at the same time may undermine conclusions and policy recommendations.

Econometric models are well suited and the only way to find empirical evidence on the double dividend hypothesis. The ILO (2009) identified three major studies that have used econometric models to analyze the double dividend of green policies. All three models are demand driven and allow for the possibility of unemployment as a result of adjustment processes, and each includes a wide range of sectors. They are therefore particularly useful for examining the inter-sectoral adjustments generated by climate change policies. In all three models, a reduction in CO₂ emissions via tax instruments conveys positive effects on employment, even when tax revenue is not recycled.
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