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# A shaft of light into the black box of CGE analyses of tax reforms

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ABSTRACT

While computable general equilibrium (CGE) analysis is a useful and widely applied method for studying tax policies, there is a challenge to present and substantiate the results. I present two analytical tools designed for this purpose. The first is a two-dimensional, diagrammatical exposition of the general equilibrium solutions of a large-scale model, reduced into a two-equation system. The second is a miniature representation of the large-scale model, which can sort out the main general equilibrium responses of the CGE model. By reducing the miniature model into the same two equations, the two devices can be combined to shed light into the black box of the model. I demonstrate how the devices can be utilised to provide economic intuition on welfare and unemployment effects of changes in taxation, exemplified by $CO_2$ taxes, VAT and payroll tax.



## 1. Introduction

Computable general equilibrium (CGE) models are useful and widely applied tools in the studies of tax policy reforms because they are able to grasp the complicated interplays among economic variables and policy instruments. However, interpreting, substantiating, and presenting results of simulations on large-scale models are challenging. The present analysis introduces pedagogical devices that may be used to shed light into the else black box of CGE models, by sorting out the main driving forces behind the macroeconomic simulation results of policy shifts. While it requires some effort to establish these model-specific tools, once set up, they can be used in forthcoming model exercises and substantially ease the analysis. For researchers and analysts working with large-scale, generic models, this up-front investment can be worthwhile both for own understanding and for providing systematic insight for academic readers.

The development of the analytical tools is inspired by Holmøy (1992)'s analysis of capital deepening. He develops a stylised version of an applied CGE model in order to study how capital expansion and foreign trade assumptions affect industrial resource allocation.[1] In contrast, the tools developed in our analysis focus on macroeconomic effects, and in particular aim to grasp the interlinkages between welfare and unemployment impacts. The tendency in the vast empirical model literature is to study welfare and employment effects separately and with different numerical models.[2]2The issue of possible welfare or employment dividends of $CO_2$ taxation by cutting other taxes have been thoroughly analysed in the previous literature; see Goulder (1995) for an introduction, Schöb (2005) for an empirical survey of welfare dividends and Mors (1995) and Bosquet (2000) for surveys of employment dividends. One obvious benefit of studying unemployment and welfare within the same framework is that accounting for unemployment effects improves the welfare estimates, as unemployment reflects unexploited labour resources. Furthermore, a model incorporating involuntary unemployment caused by imperfections in the labour markets more correctly reflects distributional implications of economic reforms through the distribution of both income and meaningful activities. Studying tax reforms in models that include both welfare and unemployment impacts will reveal possible trade-offs and co-benefits between the two.

I introduce two independent, but complementary, analytical devices designed to support welfare and unemployment analysis in CGE models. One is a diagrammatical exposition of the general equilibrium solutions, where the CGE model is reduced into a two-equation system in two variables: the welfare level and the unemployment rate. We identify the positions and slopes of the corresponding curves by means of simulations of the CGE model. By means of this graphical reduced-form representation of the model we can perform graphical shift analyses of tax reforms. The various equilibrium solutions of the model under different tax regimes boil down to different intersection points of the two curves with the resulting equilibrium welfare and unemployment impacts of the reform. A main advantage of using a two-equation graphical exposition is that the concepts and interpretations used in the analysis are quite analogous to those of partial market diagram analyses — a device that economists are familiar with. Thus, analogous interpretations of the intersection point, of being out of equilibrium, and of being on the "market" curves can be exploited.

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[1] See also Holmøy et al. (1999) for similar applications.

[2] The issue of possible welfare or employment dividends of $CO_2$ taxation by cutting other taxes have been thoroughly analysed in the previous literature; see Goulder (1995) for an introduction, Schöb (2005) for an empirical survey of welfare dividends and Mors (1995) and Bosquet (2000) for surveys of employment dividends.

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The other analytical device is an aggregate, stylised representation of the main characteristics of the CGE model. Auxiliary models of large CGE models are frequently used as tools in CGE analyses; see Adams (2005) for another, thorough and explicit example. The value-added of the current method is the reduction of the stylised model into two equations corresponding to the graphical representation described above. This facilitates using the two devices in concert. While the stylised model identifies channels through which tax reforms affect the economy, the shift analysis identifies net effects and, thus, helps in sorting dominant effects from less significant ones and concentrating on the relevant explanatory forces at play.

I demonstrate the usefulness of the tools by analysing three different tax shifts in a CGE model of the Spanish economy: increased $CO_2$ tax, reduced payroll tax and reduced VAT rates. I focus primarily on macroeconomic unemployment and welfare impacts. The numerical impacts are not the main focus of this analysis. Rather, its value-added is in its step-wise analytical procedure and its presentation of devices used for this purpose.

The two analytical tools constructed for shedding light on the dynamics of the CGE model are introduced in Section 2, together with a brief presentation of the CGE model. (Appendix A gives specifications and details of the CGE model.) Section 3 exploits the tools in concert in order to understand the benchmark graphs and the tax shift analysis in light of the attributes of the CGE model. Section 4 provides concluding remarks on the benefits and limitations of the analytical procedure.

## 2. The CGE model and the analytical tools

### 2.1. The numerical model

A CGE model gives details and quantified characteristics of real economies. This section describes how key characteristics of the Spanish economy are represented in the numerical model. It is a fairly standard, static CGE model. Its advantage compared with most similar models is that it features equilibrium unemployment. Unemployment is essential to account for in economic analysis of Spain. One obvious benefit of studying unemployment and welfare within the same framework is that accounting for unemployment effects improves the welfare estimates, as unemployment reflects unexploited labour resources. Furthermore, a model incorporating involuntary unemployment caused by imperfections in the labour markets more correctly reflects distributional implications of economic reforms through the distribution of both income and meaningful activities. Studying tax reforms in models that include both welfare and unemployment impacts will reveal possible trade-offs and co-benefits between the two.

Equilibrium unemployment in the model arises from frictions in the labour market due to lack of information, immobility, heterogeneities across jobs etc. This implies that the jobseekers will demand a mark-up on the reservation wage, which can compensate for the resources spent on job searching. The unemployed view the mark-up as given. However, it is subject to externalities from labour market changes. First, an expansion of economic activity is supposed to ease the process of finding a job, and this reduces the mark-up necessary to compensate for search efforts. Second, a rise in the unemployment rate relative to the benchmark, will reduce the mark-up factor, as the jobseekers are frightened into demanding less compensation for participating in the labour market. The model adopts the specification of the search mark-up from Balistreri (2002), as it is easily integrated within the Walrasian CGE framework. Labour supply is endogenous. This feature of the model enables us to analyse to what extent adjustments of labour supply explain changes in the unemployment rates.

Besides imperfect labour markets, the model incorporates a comprehensive description of other efficiency wedges in the Spanish economy that affect welfare, including the existing tax structure and imperfect competition in the product markets. The degree of competition is allowed to vary among industries according to observed firm concentration. Fixed costs of production and Cournot mark-up pricing are assumed. Entry and exit of firms are endogenous and ensure that fixed costs are exactly covered by the mark-up in equilibrium, i.e. industry profit is zero.

Spain is modelled as a small, open economy. Imports are modelled with the common Armington assumption that goods are differentiated by origin (domestic and foreign), while exports follow from the constant elasticity of transformation assumption. The latter can be interpreted as if there are costs of diverting deliveries between the domestic and foreign markets. This modelling ensures the observed existence of imports and exports along with production and deliveries to the domestic markets of similar products even if prices differ.

The structures of household utility, production, and factor use are disaggregated in order to represent relevant substitution possibilities decisive for the policy responses. The model also computes $CO_2$ emissions on a detailed level both from firms and households. Climate effects are not specified in the utility or production functions. The aim of the public sector is to balance revenues according to a constant, exogenous restriction, i. e., all policy changes are per assumption revenue neutral. Revenues from market sales of national $CO_2$ permits are included in the public income. Public savings are fixed, as is the current account.

The next subsections introduce the two analytical tools, first, a graphical representation of the model's general equilibrium solution, and second, a miniature model of the model designed so as to grasp the main characteristics of the model that can explain the solutions of the graphical exposition. The miniature model, together with complementary information of specifications and disaggregation in Appendix A, documents the necessary understanding of the whole CGE model. For further insight and quantified information, see Fæhn et al. (2009).[3]

### 2.2. Graphical exposition of the CGE model

By simulating the model's benchmark solution and some points in the vicinity of the general equilibrium, we will be able to construct a diagrammatical exposition of the model solution as the intercept between two curves, as illustrated in Fig. 1. As we shall see, it will be useful to construct two curves representing the labour market equilibrium and the current account, respectively. The two curves represent the model in reduced form in the two macro variables we want to analyse, the welfare level, *WF*, and the unemployment rate, *U*:

$$U = l(WF;\varepsilon) \tag{1}$$

$$U = d(WF;\varepsilon). \tag{2}$$

Eq. (1), *the labour market curve*, expresses all the combinations of welfare levels and unemployment rates that ensure that the labour market is in equilibrium, when all direct and indirect effects of *WF* and *U* on the labour market are accounted for. The labour market equilibrium in the presence of unemployment requires that $L^D = (1-U)L^S$, where $L^D$ and $L^S$ are labour demand and supply. Eq. (2), the *current account curve*, represents combinations of *WF* and *U* that ensure unaltered current account, *D*. All exogenous variables, including the $CO_2$ tax, payroll tax and VAT rates, are represented by the exogenous vector $\varepsilon$ — *the shift vector* — in the equations. Since the two equations represent the whole model in reduced form, there is only one (*WF*, *U*)-combination that fulfils both Eqs. (1) and (2) for a given set of exogenous variables/assumptions. This (*WF*, *U*)-combination is the model's general equilibrium.

The benefit of using a general equilibrium model in this reduced form is that the 2-equation model will directly give us the welfare and unemployment results. Shift analysis on the model implies that the $\varepsilon$-vector changes. This will shift both the curves, and we obtain a new equilibrium solution for *WF* and *U*. It is not possible to analytically

[3] The model in Fæhn et al. (2009) deviates from the present by having two labour markets.