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Transition towards a low carbon economy: A computable general equilibrium analysis for Poland

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HIGHLIGHTS

► Economic impact assessment of the EU climate and energy package for Poland.
► Sensitivity analysis on where-flexibility, revenue recycling and technology choice.
► Application of a hybrid bottom-up, top-down CGE model.

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ABSTRACT

In the transition to sustainable economic structures the European Union assumes a leading role with its climate and energy package which sets ambitious greenhouse gas emission reduction targets by 2020. Among EU Member States, Poland with its heavy energy system reliance on coal is particularly worried on the pending trade-offs between emission regulation and economic growth. In our computable general equilibrium analysis of the EU climate and energy package we show that economic adjustment cost for Poland hinge crucially on restrictions to where-flexibility of emission abatement, revenue recycling, and technological options in the power system. We conclude that more comprehensive flexibility provisions at the EU level and a diligent policy implementation at the national level could achieve the transition towards a low carbon economy at little cost thereby broadening societal support.

1. Introduction

Between 1988 and 2005 Poland's transition to a market economy has been accompanied by a sharp decrease in CO_2 emissions along with structural changes towards less energy-intensive production as well as overall energy efficiency improvements. However, a positive correlation between GDP and CO_2 emissions has reemerged from 2005 onwards confronting Poland with a potential trade-off between CO_2emission reduction and economic growth. While compliance to its reduction target under the Kyoto Protocol at the end of 2012 is ensured, the challenge comes along with Poland's new obligations under the ambitious EU climate and energy package which imposes an EU-wide emission decrease by 20% in 2020 compared to 2005 emission levels.

Poland is among the Top-6 emitters within the European Union accounting for roughly 8% of EU-wide emissions over the last years. The per capita emissions are similar to the EU average, but given its low income level the Polish economy comes out as among the most emission-intensive. A distinctive feature of Poland's composition of CO_2 emissions is the dominance of the power sector with an extraordinary dependence on coal. Around 85% of Poland's CO_2 emissions stem from the energy sector, in particular electricity and heat production. More than 90% of electricity is generated by lignite-fired power plants which emit the highest levels of CO_2 per unit of electricity across alternative fossil-fuel based power generation technologies—between two to three times as much as gas-fired plants.

The heavy reliance of Polish industry and power stations on coal explains concerns in Poland that stringent CO_2 emission constraints as put forward by the EU energy and climate package will not only boost domestic electricity prices but also negatively affect competitiveness and overall economic performance. How costly will it be for Poland to move to a lower carbon path? Will Poland be more burdened than the rest of the EU? How will alternative strategies to achieve the EU's emission reduction targets up to 2020 affect the magnitude and distribution of economic adjustment cost? To gain insights in these questions we make use of a computable general equilibrium (CGE) model that incorporates key determinants of economic impacts triggered by emission regulation. In our numerical simulations we find that compliance to the energy and climate

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package induces sizeable economic cost for Poland (up to a loss in real income of roughly 1% compared to a business-as-usual situation without emission regulation) that are markedly higher than for the rest of the EU. The adjustment cost for the transition to a lower carbon economy, however, could be reduced substantially through amendments of emission regulation at the superordinate EU level as well as the cost-effective policy implementation at the Member State level. At the superordinate EU level, comprehensive EU-wide emissions trading and in particular the relaxation of supplementarity constraints for the use of the Clean Development Mechanism (CDM) would allow for substantial cost savings. At the Member State level, revenue recycling of regulatory rents through wage subsidies (instead of lump-sum rebates or free allowance allocation to emission-intensive and trade-exposed industries) provides scope for a double dividend, i.e., a reduction of emissions together with reduced unemployment (and a reduction of Poland's compliance cost by two third). Relaxing expansion constraints on nuclear power is found to cut compliance cost for Poland by about one third.

This paper adds a country study for Poland to the applied economic literature on impact assessment of the EU climate and energy package. The specific methodological contribution of our CGE analysis is the focus on economic adjustment of a single EU country—in this case Poland—while accounting for important international spillovers of policy regulation through a multi-region (global) setting.[1] Furthermore, our economic impact assessment for Poland exemplifies the critical importance of where-flexibility in emission abatement, revenue recycling, and technology constraints in the electricity sector for the magnitude of economic adjustment cost towards a low carbon economy.

The remainder of this article is organized as follows. Section 2 presents the computable general equilibrium model underlying our quantitative analysis of emission regulation in Poland and the EU. Section 3 lays out alternative policy scenarios to meet the emission reduction commitments under the EU climate and energy package. Section 4 presents a discussion of the simulation results. Section 5 summarizes and concludes.

2. Computable general equilibrium model

Our quantitative impact assessment of the EU climate and energy package builds on a static multi-sector, multi-region CGE framework established by Böhringer and Rutherford (2010) for the analysis of greenhouse gas emission control strategies. We extend the generic CGE model with specific features such as labor market rigidities, the bottom-up representation of discrete technologies in electricity production, and alternative revenue recycling mechanisms to reflect central issues in the climate policy debate in Poland and the rest of the EU.

2.1. Model structure

For the general reader we restrict the model description to a non-technical summary of key features. Appendix which follows Böhringer and Rutherford (2010) provides a detailed algebraic description.

Our model includes a representative agent for each region who is endowed with three primary factors: labor, capital, and fossil-fuel resources (used for the production of fossil fuels). Labor and capital are intersectorally mobile within regions but immobile between regions. Fossil-fuel resources are specific to fossil fuel production sectors in each region.

Production of commodities other than primary fossil fuels and electricity is captured by three-level nested constant-elasticity-of-substitution (CES) cost functions that describe the price-dependent use of capital, labor, energy and material in production. At the top level, a CES material composite trades off with an aggregate of capital, labor and energy subject to a constant elasticity of substitution. At the second level, a CES function describes the substitution possibilities between the energy aggregate and the value-added composite of capital and labor. At the third level, capital and labor substitution possibilities within the value-added composite are captured by a CES function and different energy inputs enter the energy composite subject to a constant elasticity of substitution.

In the production of fossil fuels, all inputs—except for the sector-specific fossil fuel resource—are aggregated in fixed proportions at the lower nest. At the top level, this non-resource composite trades off with the sector-specific fossil fuel resource at a constant elasticity of substitution. The latter is calibrated in consistency with empirical estimates for the price elasticity of fossil fuel supply.

Final consumption demand in each region is determined by the representative agent who maximizes utility subject to a budget constraint with fixed investment (i.e., a given demand for the savings good). Consumption is captured through a CES composite that combines demand for energy and non-energy goods. Substitution patterns across non-energy goods in final consumption are reflected via a CES function; the energy aggregate in final consumption demand consists of the various energy goods trading off at a constant elasticity of substitution.

Government provides a public good which is produced with commodities purchased at market prices. These expenditures are financed with tax revenues. The impact assessment of policy interference implicitly involves revenue-neutral tax reforms in order to provide a meaningful welfare comparison without the need to trade off private consumption and government consumption. This is done by keeping the amount of the public good provision fixed and recycling any residual revenue.

Bilateral trade is specified following the Armington approach of product heterogeneity where domestic and foreign goods are distinguished by origin (Armington, 1969). All goods used on the domestic market in intermediate and final demand correspond to a CES composite that combines the domestically produced good and the imported good from other regions differentiated by demand category. Domestic production either enters the formation of the Armington good or is exported to satisfy the import demand of other regions. The balance of payment constraint which is warranted through flexible exchange rates incorporates the benchmark trade deficit or surplus for each region.

CO_2 emissions are linked in fixed proportions to the use of fossil fuels with CO_2 coefficients differentiated by the specific carbon content of fuels. CO_2 emission abatement can take place via fuel switching (inter-fuel substitution) or energy savings (either by fuel-non-fuel substitution or a scale reduction of production and final demand activities). CO_2 abatement requirements are introduced by means of an additional constraint that holds CO_2 emissions to a specified limit. Scarcity rents on CO_2 emission constraints accrue to the government.

Domestic labor markets may exhibit frictions with equilibrium unemployment. To mimic labor market rigidities we adopt a wage-curve relationship. Labor market rigidities are represented at the regional level through the specification of a wage curve (Blanchflower and Oswald, 1995). The wage curve reflects empirical evidence on the inverse relationship between the level of wages and the rate of unemployment which can be derived in

[1] Böhringer et al. (2009) compare various impact studies of the EU climate and energy package but none of these studies treat Poland explicitly. Bukowski and Kowal (2010) provide a climate policy impact assessment for Poland based on a dynamic stochastic general equilibrium (DSGE) model but do not account for international feedback and spillover effects as they adopt a single-region framework.