Structural Change and Economic Dynamics 37 (2016) 62–74

Contents lists available at ScienceDirect

Structural Change and Economic Dynamics

journal homepage: www.elsevier.com/locate/sced

Structural and climatic change

Gustav Engström *

The Beijer Institute of Ecological Economics and Global Economic Dynamics and the Biosphere, The Royal Swedish Academy of Sciences, P.O. Box 50005, SE-104 05 Stockholm, Sweden

ARTICLE INFO

Article history:
Received January 2014
Received in revised form June 2015
Accepted November 2015
Available online 17 December 2015

JEL classification:
Q54
O41
O44

Keywords:
Structural change
Climate change
Economic growth

ABSTRACT

This paper studies a multi-sector growth model where emissions from fossil fuels give rise to a climate externality. Each sector is impacted heterogeneously by climate change which together with technological differences induces factor reallocation over time. By solving the social planners problem and characterizing the competitive equilibrium this paper derives a simple formula for optimal taxes and sectoral factor allocation which shows how the elasticity of substitution between sectors impact on taxes through differences in technology as well as sensitivity to climate change. I also present separate numerical simulations for how optimal policies differ depending on sectoral composition, exemplified by the U.S and Indian economy. The results show how climate change,Please check the telephone number and the email address of the corresponding author, and correct if necessary. technological development and the elasticity of substitution can impact on optimal fossil fuel consumption over time.

1. Introduction

Integrated assessment models (IAMs) have been around for a long time now and have become principle tools of investigation when it comes to quantitatively assessing the social cost of carbon (SCC). The models come in a wide variety of different shapes and sizes but those that receive the most attention among economist's are the ones that describe the coupled dynamic interaction between climate change and economic growth and that can be used to explore optimal policies for curbing carbon dioxide emissions in the future.[1] Among these models, the vast majority are globally aggregated and thus only contain aggregate measures of variables such as GDP or temperature levels at the global scale.[2] This is also the case when it comes to the sectoral decomposition of the economy. Policy optimizing IAMs are typically single-sector models, and little attention is thus paid to how the sectoral composition or other structural aspects of the economy matter for how different sectors are impacted by climate change. To the best of my knowledge there has to date, been no comprehensive attempt to extend the single sector IAM framework to include the structural or sectoral impacts of climate change on economic growth in a general equilibrium framework.

In this paper, I try to remedy this shortcoming by constructing an n-sector IAM model with typical elements that allow for the analysis of both structural and climatic change in an optimal growth context. This will allow us to (i) show how substitution possibilities between goods and heterogeneous sectoral impacts from climate change matter for factor allocation decisions across sectors and (ii) explore what the sectoral decomposition and its underlying assumptions imply for aggregate fossil fuel use and distribution across countries and regions over time (see e.g. Brock et al. (2013, 2014)).

* Tel.: +46 8 673 97 10.

[1] For a review of the different types of IAMs see Kelly and Kolstad (1999). For one of the earliest contributions, see Nordhaus (1977).

[2] Regional models do however exists. One of the earliest attempts is Nordhaus and Yang (1996). Regional IAMs have e.g. revealed the heterogeneous impacts of climate change and their typically uneven

http://dx.doi.org/10.1016/j.strueco.2015.11.007

climate change in general and how this compares to the standard single-sector IAM. The analysis builds upon previous work in macro seeking explanation to the dynamics of structural change and economic growth, in particular the work by Ngai and Pissarides (2007) and Acemoglu and Guerrieri (2008). This literature has shown that differences in technological growth rates across sectors can be important in explaining trends and movements of capital and labor across sectors of the economy over time.[3] Given that climate change also impacts on technological growth and productivity levels (a common assumption in many IAMs), suggests that this type of analysis may be important when deriving a sectorally disaggregated IAM.

The present paper also builds upon the work by Hoel and Sterner (2007) and Sterner and Persson (2008). Their analysis has shown why disaggregation at the sector level may be important for the SCC in IAMs. In particular, they show how assumptions regarding substitutability among goods can have a potentially large impact on optimal mitigation policies in IAMs.[4] Standard, economic models featuring a climate externality typically ignore these effects. An implicit assumption embedded in most IAMs is thus that both consumption goods and intermediate inputs to production are perfect substitutes.[5] The paper by Sterner and Persson (2008) experiments with one such model, the well-known DICE model (Nordhaus, 2007). They show that when a complementary environmental good is introduced into the utility function of the DICE model this can have a dramatic impact on the optimal mitigation policy.[6] The result arises due to differences in growth rates of the two consumption goods which affect relative prices and thus leads to an increase in the cost of climate change.

A shortcoming of the above analysis is however that it ignores the inherent ability of the economy to adapt to the changes in relative prices. For example, as the environmental good in the Sterner and Persson (2008) model grows scarcer, and the relative price of that good thus increases, an optimal strategy might be to redirect resources towards its preservation.[7] In the present paper I account for this possibility by exploring how the economy can adapt by transferring resources between different economic sectors depending how they are valued and on how hard they are impacted by climate change. The paper can thus be viewed as an extension of the economic model in (Hoel and Sterner, 2007; Sterner and Persson, 2008) to include also intra-temporal adaptive behaviour. The present paper differs from these papers in at least three important ways. First, it develops an n-sector economic growth model where each sector is impacted heterogeneously by climate change. This is a first step towards deriving a more general framework for studying sector specific climate damages. By considering a model with specific sectors this allows one to calibrate the model to sector specific data. Specific impacts on the agricultural sector may be of particular interest here since it is highly dependent upon the surrounding environment such as temperature and precipitation. Second, in the present paper I allow for endogenous and free mobility of resources between the different sectors. By doing so I follow in the tradition of a vast literature on multi-sector growth models. Within the climate-economy framework considered here this assumption also has a useful interpretation in terms of adaptation costs to climate change. Here, we can think of resources flowing into the most heavily damaged sector as the opportunity cost of mitigation, implying that there exists a trade off between mitigation and adaptation decisions within the model. Finally, I model substitution decisions as a supply side phenomena i.e. I look at substitution among intermediate inputs in final output. This is perhaps more of a technical aspect that increases the analytical tractability of the model. However, as will be shown the equations governing structural change are close to identical to those of Ngai and Pissarides (2007) when the climate externality is ignored. The model developed here also draws upon work by Golosov et al. (2014). They show that given four specific assumptions (i) logarithmic utility, (ii) climate damages being proportional to output, (iii) the stock of atmospheric carbon dioxide grows linearly in emissions and (iv) a constant saving rate, it is possible to derive a simple formula for the marginal externality cost from the emissions of carbon dioxide. These assumptions also turn out to be particularly useful for deriving analytical results in the n-sector setting.

Apart from analytical results for the general n-sector economy, the paper also derives numerical results based on a simple calibration and simulation exercise for a two-sector economy featuring an agricultural sector and non-agricultural sector. I calibrate and run two simulations of optimal policies using the U.S and Indian economy as examples of two structurally distinct economies. Already in the seminal article by Arrow et al. (1961) it was pointed out that systematic inter-sectoral differences in the elasticity of substitution and income elasticities of demand, imply

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[3] The idea was first suggested by Baumol (1967) and was introduced in the context of a model of balanced economic growth by Ngai and Pissarides (2007) and Acemoglu and Guerrieri (2008).These later studies showed that both productivity and capital intensity differences among sectors can help explain the post-industrial flow of capital and labor from the agricultural sector into the manufacturing and service sectors. Acemoglu and Guerrieri (2008) do not attempt to explain the flow of capital and labor from agriculture into manufacturing, however later unpublished work by Lin and Xu (2011) show that this could have been explained within the context of their model. See also Kuznets (1957), Chenery (1960), Kongsamut et al. (2001) for alternative explanations of structural change.

[4] These papers do however not consider the intra-temporal adaptation capabilities of economies which is something I will explore in terms of sectoral factor movement.

[5] Examples of such aggregate models can be found in a recent review by Stanton et al. (2009).

[6] This was done replacing the standard consumption good with a composite good consisting of, an ordinary consumption good and environmental consumption good, aggregated together using a constant elasticity of substitution (CES) function. Assuming the two goods are complements in utility and a constant growth rate in ordinary consumption, this implied a rising relative price over time for the environmental good. Weitzman (2010) shows that under their specific assumptions regarding the elasticity of substitution this specification becomes equivalent to introducing an additive damage function affecting utility directly.

[7] This assumes however that transaction or transfers costs are not too large.