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Knowledge diffusion, endogenous growth, and the costs of global climate policy

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ABSTRACT

This paper examines the effects of knowledge diffusion on growth and the costs of climate policy. We develop a general equilibrium model with endogenous growth which represents knowledge diffusion between sectors and regions. Knowledge diffusion depends on accessibility and absorptive capacity which we estimate econometrically using patent and citation data. Knowledge diffusion leads to a "greening" of economies boosting productivity of "clean" carbon-extensive sectors. Knowledge diffusion lowers the costs of global climate policy by about 90% for emerging countries (China) and 20% for developed regions (Europe and USA), depending on the substitutability between different knowledge types.

1. Introduction

Knowledge capital accumulation and technology are important drivers for economic growth. In open economies, sharing knowledge—in contrast to acquiring rival factor inputs such as human and physical capital—provides an inexpensive way of fostering endogenous innovation (Eaton and Kortum, 1999; Keller, 2002). To the extent that knowledge diffusion enhances the productivity of "clean" carbon-extensive relative to "dirty" carbon-intensive inputs, it can also lower the costs of environmental regulation, in particular of policies that act on an international level, such as global carbon mitigation policies to combat climate change. Leading economic analyses have scrutinized the interactions between the environment, growth, and technology. For example, Nordhaus (1994) and Stokey (1998) show that growth can be limited by environmental constraints, while Aghion and Howitt (1998) and Acemoglu et al. (2012) demonstrate that sustainable growth is possible with climate policy that redirects innovation toward clean inputs. Also, firms may innovate more in clean technologies when they face a climate policy (Aghion et al., 2016; Calel and Dechezleprêtre, 2016). The role of knowledge diffusion for economic growth and for the costs of environmental regulation, however, has received surprisingly little attention.

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This paper develops a multi-sector multi-region endogenous growth model to study the effects of knowledge accumulation and diffusion for growth and the costs of global climate policy. Following endogenous growth theory (Aghion and Howitt, 1992; Helpman, 1992; Romer, 1990), knowledge, or technology, is non-rival in the sense that the marginal costs for an additional firm or individual to use the technology are negligible. In addition to knowledge spillovers among firms within a sector, we represent knowledge diffusion between sectors and regions. We distinguish between knowledge flows originating from a shared knowledge pool (Adam, 1990; Stiglitz, 1999) and their subsequent effects on knowledge creation reflecting the idea of accessibility and absorptive capacity of external knowledge (Haskel et al., 2007; Lane and Lubatkin, 1998). Absorptive capacity positively depends on the existing stock of knowledge capital. As green sectors tend to be relatively capital-intensive, knowledge diffusion is higher among clean relative to dirty sectors—which is in line with recent empirical findings (Aghion et al., 2016; Calel and Dechezleprêtre, 2016; Dechezleprêtre et al., 2014).[1] These technology effects are included in a fully specified general equilibrium model which is (1) based on econometrically estimated knowledge diffusion processes using patent and citation data and (2) calibrated to sectoral production, consumption, and international trade patterns of four major world regions.[2]

Our model highlights *size effects* and *competition effects* through which knowledge diffusion affects growth and costs of climate policy. Size effects positively impact the productivity of firms which benefit from knowledge flows, hence lowering the production costs of production. Competition effects change the pattern of comparative advantage between sectors and regions to the extent that the accessibility and absorptive capacity of knowledge differs among firms, both across sectors and regions. While for a closed one-sector economy knowledge diffusion works solely through a size effect, the direction of the competition effect and relative magnitudes of both effects are a priori unclear in a multi-sector and multi-region general equilibrium framework. To the best of our knowledge, our paper is the first to develop a systematic framework for the analysis of domestic and international knowledge diffusion in a fully specified general equilibrium model with endogenous growth that permits investigating the costs of global climate policy.

Our analysis shows that knowledge diffusion, through both size and competition effects, leads to a “greening” of economies. Sectors with relatively low carbon intensities are characterized by high knowledge capital intensities, implying a large absorptive capacity. Knowledge diffusion thus boosts the productivity of these “clean” carbon-extensive sectors by more than it does for “dirty” carbon-intensive sectors. This, in turn, decreases the production costs of “clean” (non-energy) relative to “dirty” (energy) goods. When energy (carbon) inputs become more expensive under a climate policy regime, the costs of substituting away from carbon-intensive goods are hence lowered because “clean” goods can be produced at lower costs. This positive effect is re-enforced over time and across markets and space: “clean” sectors with higher productivity increase market shares in total output over time and benefit from increased competitiveness on domestic and international markets.

Notably, we find that the costs of a global climate policy, achieving a given (absolute) reduction of carbon dioxide (CO_2) emissions, can be substantially lowered through this “greening” effect arising from domestic and international knowledge diffusion. For regions with relatively little own knowledge (e.g., China), reductions can be up to 90%. For developed regions (e.g., Europe and the U.S.), policy costs can decrease but also increase depending on the strength of the “greening” effect. If the substitutability between different types of knowledge is high, costs are reduced by up to 20%. However, the costs of climate policy for these regions slightly increase when the substitutability is low. A simple but important implication of our analysis is, that in order to control emissions, carbon pricing policies should be complemented by R&D policies aimed at promoting knowledge diffusion. While this general insight is not novel (see, e.g., Acemoglu et al., 2012), we provide further support for this argument view by focusing on the effects from knowledge diffusion that could be created through R&D policy.

The impacts of knowledge spillovers on economic growth are substantial, corresponding to welfare gains for the global economy of about 4–10%; they depend on the substitutability between different types of knowledge. Regions with initially relatively low knowledge (e.g., China) benefit the most from knowledge diffusion whereas developed regions (e.g., Europe and U.S.) gain relatively less. In line with previous analyses (Eaton and Kortum, 1999; Keller, 2002), we find that the major sources of technical change leading to productivity growth are not domestic but, instead, lie abroad: international knowledge spillovers account for two thirds of the increase in knowledge capital due to knowledge diffusion, domestic spillovers contribute one third.

Our paper is related to the literature in several ways. We introduce knowledge spillovers between sectors and regions into the endogenous growth model (Aghion and Howitt, 1992; Helpman, 1992; Rebelo, 1991; Romer, 1990) in which profit-motivated industrial innovations in R&D *within a sector* lead to the accumulation of technological knowledge which is only partially excludable and non-rival, and hence, becomes a source of growth. Investigating knowledge diffusion in an endogenous growth model is important because gains from endogenous innovation are compounded to the extent that knowledge can be shared.

[1] Dechezleprêtre et al. (2014) find that clean patents receive on average 43% more citations than dirty patents and are also cited by more prominent patents. The reasons are that clean technologies have more general applications and that they are radically new compared to more incremental dirty innovation.

[2] We include China, Europe, USA, and an aggregate world region.