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Subsidizing Human Capital to Overcome the Green Paradox—A Demand-Side Approach

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Abstract

This paper shifts the perspective of the recent green paradox literature towards the demand side. Based on a simple model, I show that a subsidy on input factors in a Cobb-Douglas production functionmay contribute substantially to postponing resource extraction into the future and, thereby, to limit the future costs of climate change. Specifically, indirect subsidies on human capital, such as investments in education, are plausible policy options to mitigate carbon dioxide emissions because it is robust to short-sighted incentives on the part of politicians and resource owners.

Keywords: climate change, Demand-Side, green paradox, subsidy

1. Introduction

This paper makes on original contribution to the field of resource and environmental economics. It shifts the perspective of a recent strand of the green paradox literature towards the demandside by providing a simple model that analyses the intertemporal effect of subsidizing human capital as a (non-perfect) production input substitute for non-renewables.

Climate change has become one of the most severe problems facing mankind. Consequently, several policies have been discussed and introduced, although most of them were said to suffer from the green paradox. The term green paradox, stemming from Sinn (2008), describes policies that are intended to mitigate carbon dioxide (CO_2) but actually accelerate carbon production and CO_2 emissions in the short run because they only focus on the demand side and do not consider supply side effects. Specifically, policies that aim at emission savings far in the future (e.g., the Kyoto Protocol) provide incentives to resource owners to increase their current resource production. Therefore, during the last decade, much effort has been put into analysing the green paradox, as well as on the credibility and reliability of climate policies.

However, as already noted by DiMaria, Lange & Werf (2013), the demand side of the resource market has been virtually ignored. Therefore, this study analyses the role of (non-perfect) input substitutes—resources and capital—in the production function on the demand side against the backdrop of climate change and the green paradox. I build a model in which resource owners and resource consumers strive to maximize their utility over time. Based on this model and by applying different numerical setups within a Vensim simulation, I show that even very low rates of time-varying and slightly increasing subsidies for human capital help reduce the total costs of climate change if resources, physical capital and human capital are considered as production inputs. This reduction in climate costs is achieved by an increase in the future marginal product of the resources that comes with postponed extraction and the flattening of the extraction path. Furthermore, I provide evidence that such a policy does not lead to a green paradox because the initial unit price of a resource increases and, thus, does not cause carbon leakage if this strategy is applied in only one part of the world. On the contrary, a decreasing subsidy over time generates a green paradox because the ratio of the present to future marginal product of the resource increases.

The remainder of this paper is structured as follows: First, I provide a short overview of the relevant literature on the green paradox. Second, I describe the theoretical model and estimate the model using several input setting. Thereby, I show the effect of a subsidy on human capital on the extraction and price path, as well as on the avoided climate cost. Finally, I discuss the policy implications and state the main outcomes of this theoretical approach.

2. Overview of the Literature

Among other policies, Sinn (2008) analyses the effect of an announcement of a carbon tax with a steeply increasing time path. He shows that the expectation of decreasing resource profits in the future induces resource owners to extract their dirty resources more rapidly in the present. This argument is in line with that of Sinclair (1994), who shows that a carbon tax must follow adecreasing time path. In addition to taxes on fossil fuels, subsidies on renewables have been subject to detailed analysis. Grafton, Kompas & Long (2012) examine the way subsidies on renewable energy sources influence the extraction of non-renewables. They find that subsidies produce a green paradox if the supply curves of renewables are concave. Long (2013) examines the substitutability of renewables and non-renewables. He shows that technological improvements that increase substitutability produce higher present emissions because resource owners anticipate future shrinking demand. As noted by Hoel (2013), who analyses supply-side policies, the removal of high-cost reserves is accompanied by a flattening extraction path as long as a clean backstop technology is available. On the contrary, the removal of low-cost reserves from the extraction process may come with a rise in the extraction path and, thus, with an increase in early and total emissions. Hence, there is a possibility that even policies that directly limit the amount of reserves are subject to the occurrence of the green paradox.

Furthermore, technological innovations such as backstop technologies or carbon capture and storage (CCS), which have high potential to mitigate carbon emissions, have become subjects of the green paradox and related strands of literature. In a two-period model, Hoel & Jensen (2012) analyse the interdependence of renewable energy sources and CCS technologies under an imperfect climate policy. They find that, in terms of the green paradox, it more desirable to see innovation on part of CCS technologies than on part of the renewable because resource owners are otherwise incentivised to increase their present production. This result is of high relevance because Steinkraus (2016) outlines that CCS technologies are already competitive with enewable even if a cradle-to-grave perspective is considered. Winter (2013, 2014) examines the effect of innovation regarding clean energy, as well as more efficient production technology and finds evidence for the so-called innovation green paradox because all kinds of innovations may increase the net damage resulting from global warming.

Despite a broad theoretical literature, DiMaria et al. (2013) find little empirical evidence regarding the green paradox because of constraints on the demandside, which are hard to overcome in the short run. Hence, they conclude that it is important to investigate the supply side and the demand side in an integrated model.

3. Model

It remains questionable whether influencing the price path of other input factors on the demand side, such as human capital, also leads to a green paradox or has the potential to cause sustainable, or at least a temporary decrease in, greenhouse gas emissions. One could think of the following ambiguous effect. An increasing subsidy on human capital leads to higher inputs of human capital in the future. Consequently, the marginal product of the resource also increases. However, the price of the resource must still equal the marginal product and must increase with the relevant interest rate. Therefore, the future resource input either rises (in comparison to the no subsidy case) if the marginal product grows at a higher rate than the interest or decreases otherwise.

To analyse this effect, I proceed in two steps: First, I introduce a simple model that applies the Hotelling rule to the demandside. This demandside is supposed to represent a synthetic demand consisting of most resource-consuming industries. These industries produce final goods by means of a Cobb-Douglas function similar to that in Stiglitz (1974), because it requires that a minimum level of resources is needed as input factor to produce the goods regardless of the human capital input. Moreover, it also ensures meeting the transversality condition. Second, I use Vensim to estimate this model using different parameter settings. By doing so, I show the time path of resource extraction, as well as the price path for two different scenarios: no subsidy on human capital and a slightly increasing subsidy. Finally, I compare the extraction rates of both scenarios to calculate the amount of climate change costs that can be avoided by applying the subsidy.

3.1 Positive Analysis

On the supplyside, there are many resource owners j in a competitive market who are all price takers and strive to maximize their total utility U over time$t$:

$$max \int_0^\infty U(C_j)e^{-(\rho\cdot t)}\, dt, \tag{1}$$

where C denotes consumption, and ρ is the social discount rate. The resource owners are constrained by the following conditions:

$$\dot{S}_j = -R_j \tag{2}$$

$$\dot{V}_j = p \cdot R_j - C_j + s \cdot V_j, \tag{3}$$

where S is the stock, and R is the depletion of the resource. V denotes the assets of j that yield an interest of s. For simplicity, I neglect extraction costs because the results are quite similar. Applying the standard Hamiltonian approach, the fundamental Hotelling rule follows. The relative change in resource prices $\hat{p}$ must equal the relevant interest rate (Please note that a dot denotes the first derivative with respect to time and a hat denotes the relative change over time):

$$\hat{p} = s. \tag{4}$$

On the demandside, producers of final goods d also strive to maximize their utility according to equation (1). However, they face different constraints. First, their capital stock increases via production $F(K, H, R)$ and investments I but decreases by the sum of spending for consumption, input factors (w denotes the wage for human capital H) and capital costs (c is the weighted average of the cost of capital, which is not required to but may equal s). Second, investments increase liabilities and equity LE.

$$\dot{K}_d = F(K_d, H_d, R_d) + I - C_d - p \cdot R_d - w \cdot H_d - c \cdot LE_d \tag{5}$$

$$\dot{LE}_d = I_d \tag{6}$$

Based on these constraints the Hamiltonian yields the following textbook-like conditions for the optimal path:

$$\frac{\partial F_d}{\partial K_d} = c, \frac{\partial F_d}{\partial H_d} = w, \frac{\partial F_d}{\partial R_d} = p. \tag{7-9}$$

Considering a decreasing returns to scale, $(\alpha + \beta + \gamma < 1)$, Cobb-Douglas production function, $F(K, H, R) = K^{\alpha} H^{\beta} R^{\gamma}$, the price path of equation (4), constant capital costs and the possibility of a time-varying subsidy $T(t)$ on the cost of human capital, $(w(t) = w_0 - T(t))$, the three following conditions describe the optimal paths for capital, human capital and resource consumption:

$$\alpha\widehat{K_d} + \beta\widehat{H_d} + (\gamma - 1)\widehat{R_d} = \hat{p} = s \tag{10}$$

$$\alpha\widehat{K_d} + (\beta - 1)\widehat{H_d} + \gamma\widehat{R_d} = \hat{w} \tag{11}$$

$$(\alpha - 1)\widehat{K_d} + \beta\widehat{H_d} + \gamma\widehat{R_d} = 0. \tag{12}$$

Solving equations (10-12) for $\hat{R}$ yields:

$$\widehat{R_d} = -\frac{s \cdot (1 - \alpha - \beta) + \beta \cdot \hat{w}}{1 - \alpha - \beta - \gamma}. \tag{13}$$

Although subsidizing (human) capital is not said to have an impact on long-term economic growth (Groth & Schou, 2007), it seems to be a relevant impact factor on the path of resource extraction. On the one hand, it becomes obvious that an increasing tax or a decreasing subsidy on human capital has a deteriorating effect on climate change because a positive $\hat{w}$ causes a steeper extraction path. On the other hand, a subsidy on human capital that follows a bounded growth function, such as $T(t) = w_0 - w_0 \cdot e^{-k \cdot t}$, comes with relative change in net wages $\hat{w}$ of $-k$ and may contribute substantially to flattening the extraction path. As a positive side effect, $\hat{R}$ becomes a constant variable. Based on the transversality condition and $\frac{dR}{dS} = -\hat{R}$, the initial resource production can easily be computed by:

$$R_0 = S_0 \cdot \hat{R}. \tag{14}$$

Thus, as long as $k < \frac{s \cdot (1 - \alpha - \beta)}{\beta}$ holds, the initial resource production decreases as k increases.

3.2 Resource Extraction, Climate Costs Avoided and Price Path

Allen et al. (2009) assume that the maximum global temperature increase depends on the total amount of CO_2 equivalent emissions but not on the time path of those emissions. However, the costs of climate change are higher the earlier the maximum increase is reached and the more rapidly the increase occurs (Hoel, 2012).

Consequently, a suitable way to limit the costs of climate change is to postpone extraction far into the future. To calculate the extent to which a subsidy on human capital can influence the extraction path and thereby the costs of climate change, I estimate a Vensim modelusing several input configurations.

In a first step, I compare the impact of a very low subsidy with $k = 0.005$ (since the subsidy follows a bounded growth approach, $k = 0.005$ means that net costs of human capital decrease approximately 5 per cent within ten years) on the extraction path and the remaining storage stock to the no subsidy scenario for four different output elasticity combinations (see Figures 1 and 2). The output elasticities are in line with the results obtained from Mankiw, Romer, & Weil (1992), although their production function is slightly different. In all simulations, the interest rate s and cost of capital c are set to 0.1 (see e.g., Dhaliwal, Heitzman, & Li, 2006). The cost of human capital w is also set to 0.1. Based on this figures, the simulation results reveal that the aggregate costs of human capital account for 30 to 50% of the overall production revenue, which can be assumed to be close to real world ratios (see e.g., Korpi, 2002). The initial resource stock is assumed to be 1000. I also use different parameter settings but results are similar. Based on the simulation results, it becomes obvious that resource extraction is lower in the case of subsidies for the first two to three periods. Consequently, during the early periods, I observe a significantly higher resource stock in situ. This effect becomes even stronger when the output elasticity of human capital increases.

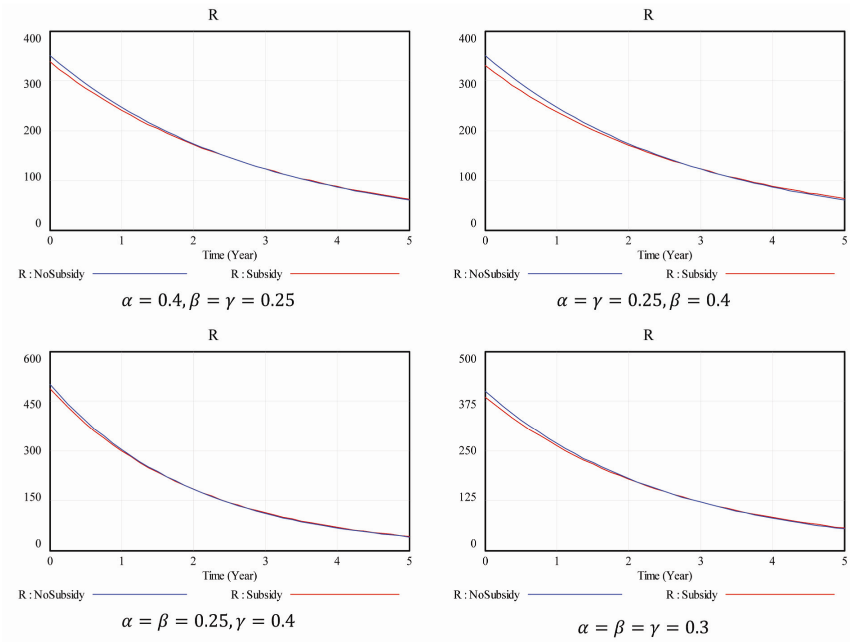

Figure 1. Resource extraction

Source: Own calculation.

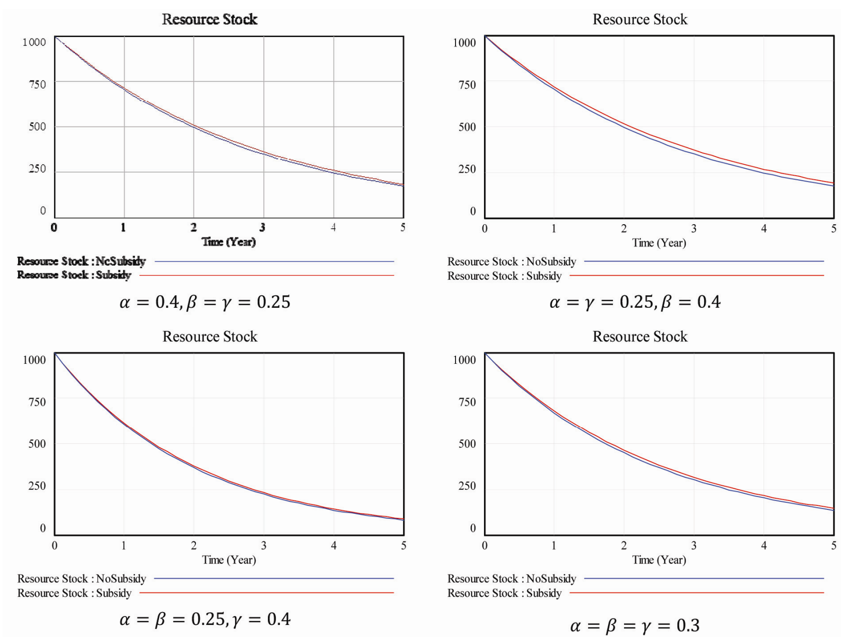

Figure 2. Resource stock

Source: Own calculation.

In a second step, I measure the effect of delayed extraction on climate costs, which can be seen as the external effect of resource production. To do so, I follow Allen et al. (2009) and Hoel (2012) and use an approach similar to Sinn (2008). I assume that each unit of extracted resource causes short-run costs of climate change amounting to 1 unit per period after it has been extracted. Therefore, the sum of avoided external climate costs equals the integral of the difference between the resource stock in the cases with and without subsidies. The results for the different elasticities are shown in Figure 3. Again, the higher the output elasticity of human capital, the more costs of climate change can be avoided by applying the subsidy.

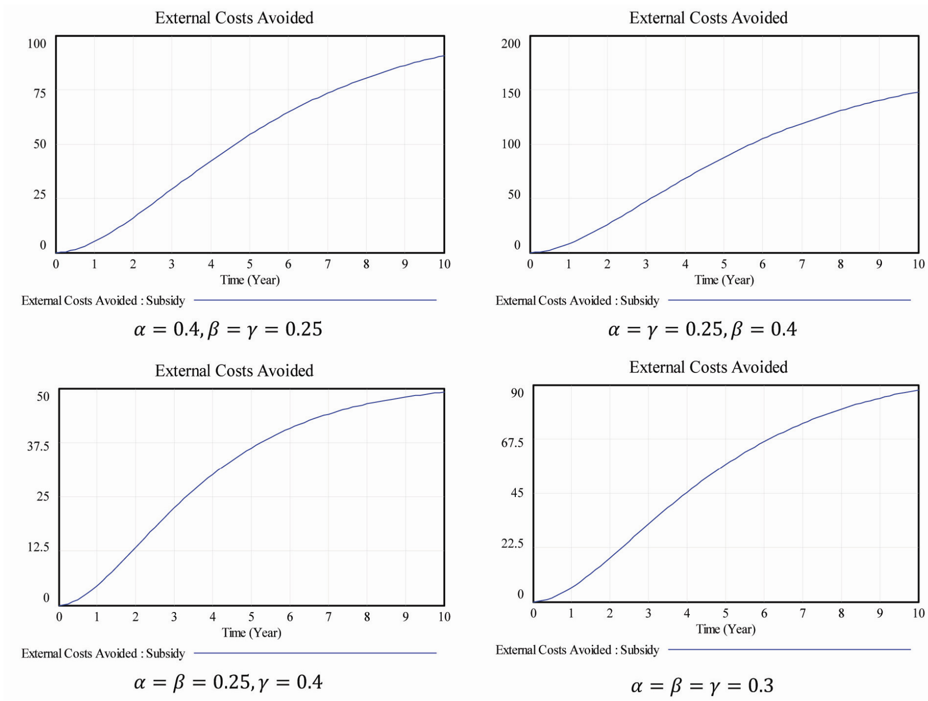

Figure 3. External costs avoided

Source: Own calculation.

However, these positive outcomes only occur if there is no carbon leakage linked to the subsidy. Carbon leakage is a phenomenon that gives rise to a green paradox and may emerge if only some countries in the world attempt to reduce their carbon emissions, e.g., by introducing a subsidy while other countries do not. Because of unilateral mitigation strategies, the world price of carbon decreases and undermines carbon reduction attempts by shifting the fossil fuel consumption towards non-compliant countries. This effect is said to be stronger in case of export-driven markets supporting mitigation policies (see, e.g., Barker, Junankar, Pollitt, & Summerton, 2007; and Hoel, 2013). To control for possible leakage, I more closely examine the initial price levels of the resource in both cases. Based on Figure 4—which show the price difference in the subsidy and no-subsidy cases—it becomes obvious that $p(t = 0)$, and thus, the price level in all following periods is higher if a subsidy is introduced. Therefore, I conclude that a demand policy, as mentioned above, does not suffer from carbon leakage even if it is adopted only in some countries. In addition, this argument is not valid exclusively from a global perspective. The initial price increase reduces resource consumption in other sectors that cannot be captured within the assumed production function.

How the subsidy should be funded remains an open question. Hence, I checked whether a time path of the subsidy suggested above comes with a positive net welfare effect. The net welfare effect NWE is defined as the sum of changes in the social utility function caused by the subsidy over time:

$$NWE = \int_0^{\infty} dU\, e^{-\rho \cdot t} dt = \int_0^{\infty} U' \cdot dC\, e^{-\rho \cdot t} dt \quad (15)$$

where dC denotes the change in society's consumption. This term consists of the following effects:

$$dC = ClimateCostsAvoided + ProductionSurplus - CostsofSubsidy. \quad (16)$$

The costs of the subsidy arise from the product of the total human capital input and the time-varying subsidy. Based on a Monte Carlo simulation strategy and some sensitivity checks, I find that the change in consumption is most sensitive to the costs of climate change. In addition, after approximately two periods, the subsidy's impact on the outcome of production becomes positive in all simulations. In total, even for very low external climate costs, the consumption effect is positive over the entire period for most simulations. Therefore, the net welfare effect is positive and independent of the choice of the utility function as long as it is monotonically increasing. Consequently, it can be argued that the subsidy is likely to be self-financing.

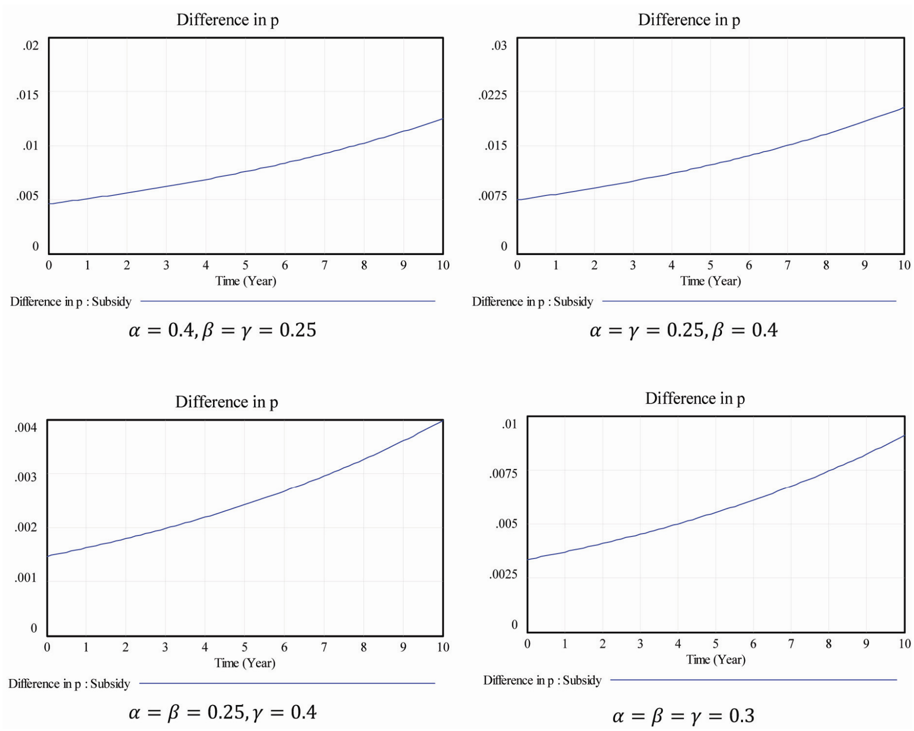

Figure 4. Difference in resource prices

Source: Own calculation.

4. Conclusions and Policy Implications

Based on a simple model, I extended the shift of the recent green paradox literature towards policy opportunities on the demandside. I showed that subsidizing other input factors of the production function, such as human capital, has the potential to substantially flatten the resource extraction path. This finding results from the higher future marginal product of resources. Furthermore, costs of climate change can be reduced by postponed carbon dioxide emissions. In contrast to other carbon mitigation strategies that have been widely discussed, such as higher taxes on carbon, a subsidy on input factors does not produce a green paradox. Higher initial resource prices prevent other nations or sectors from increasing consumption and, thus, greenhouse gas emissions.

However, similar to other policies that aim to minimize the dangers and costs of climate change, an increasing time path of a subsidy on input factors has both strengths and shortcomings. First, a subsidy can be considered more effective than a tax on carbon because no one can expect to avoid receiving a subsidy, whereas resource owners and producers of final goods try to avoid taxes. Second, although subsidizing input factors may be a political tender point, subsidizing human capital as an input factor might resolve this issue. Specifically, indirect subsidies, such as investments in education, are honoured by people and reduce the costs of human capital because firms do not need to exert much effort to further educate their employees. This argument is highly relevant because my results suggest that the effect of a subsidy on the extraction path is more pronounced when the output elasticity of human capital is higher. Thus, high technology sectors with well-educated and highly skilled workers should receive subsidies for educational investments. Third, another problem that may occur in context of subsidies involves credibility. Politicians always have incentives to cut subsidies on input factors to relieve budgetary pressure. This incentive is intensified by the fact that resource extraction falls, especially right after the start of a subsidy. The later extraction rates cannot be distinguished between the subsidy and no-subsidy cases. This is a crucial point becausea cut in the subsidy comes with a higher present marginal product of the resource and, thus, deteriorates the ratio between the future and present marginal product. If resource owners anticipate this behaviour, they will increase today's extraction and accelerate global warming. On the contrary, this problem can also be cured by an indirect subsidy, such as investment in education. The results of investments in education come with a time lag and have long lasting effects. Hence, these features prevent side effects from short-sighted political decisions and prevent premature resource extraction due to higher future marginal products of resource inputs.

It remains questionable whether the subsidy has a cross-region effect on the movement of human and other capital and firms from no-subsidy towards subsidy countries, which may deteriorate the resource extraction rates. However, there is now incentive for a cross-border movement of capital and human capital, because neither net-wages nor the interest rate is affected by the subsidy. On the contrary, a cross-border movement of firms cannot be ruled out since they want to enjoy the decreasing costs of human capital. Of course, this trend has a positive impact on the extraction path because the number of firms, which endogenously cause a higher present marginal product of the resource, increases.

Based on the model and outlined results, it is obvious that there is considerable potential on the demandside to mitigate carbon dioxide emissions without creating a green paradox. However, policies must still be chosen and applied thoughtfully because the threshold between real green policies and paradox-inducing policies is very small. More detailed analyses of the demandside are needed to guide politicians along green side of the threshold.

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