Nature Climate Change Comment

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TITLE

Green premia are a challenge and an opportunity for climate policy design

STANDFIRST

Adjusting green public support programs to green premia can reduce public spending, yet this is challenged by uncertainty. Responsive adjustments reduce risks of underfunding green technologies, thereby delaying the green transition, and risks of overfunding them, which increases transition costs.

MAIN TEXT

To meet the Paris Agreement's climate goals, countries must transition from emission-intensive to low-emission (green) products. This transition requires substantial changes, including switching from combustion engines to electric vehicles, decarbonizing industrial processes to move from emission-intensive to green basic materials, expanding renewable electricity generation, and retrofitting the housing stock.

Currently, most green products have higher production costs than their emission-intensive counterparts, making investments in green production facilities less profitable. Mainstreaming green products requires closing this profitability gap. This can be achieved through a combination of elements: 1, technological learning, which reduces incremental costs of green production; 2, effective carbon pricing, which increases the costs of emission-intensive production. In the following we will, for simplicity, combine both aspects and refer to *incremental costs* as the incremental costs net of carbon prices. A third element is the use of green public support programs (e.g., carbon contracts for differences[1,2] (CCfDs) for clean production processes or support mechanisms for renewable energy), which can increase the level or stability of revenues and reduce the costs of green production technologies. Besides these well-known elements, consumers paying a price premium for green products, i.e., a *green premium,* can also reduce the profitability gap.

To facilitate investments in green production processes, green public support programs need to bridge the difference between incremental costs and the green premium, henceforth, green profitability gap. However, the green premium in a given sector is often, *ex-ante,* uncertain, leading to uncertainty about the size of the green profitability gap. This creates a challenge for the design of green public support programs: If the support level does not match the green profitability gap, there will either be underfunding, delaying the transition, or overfunding, imposing unnecessary costs on public budgets.

With the emergence of green basic materials, it will become possible to set up green value chains. Consequently, more green final products will enter the market, which makes green premia increasingly relevant. We first review the evidence on green premia before presenting options for including them in the design of green public support programs while taking into account uncertainty on their magnitude and development.

Willingness to pay for green products and green premia

Many consumers are willing to pay more for green products than for emission-intensive ones. We refer to this difference in willingness to pay as green willingness to pay (green WTP). Green WTP can lead to market equilibria where green products are sold at higher prices than their emission-intensive counterparts, creating a price difference known as green premium (we only discuss green premia resulting from consumers' willingness to pay, and not green premia caused by regulations such as green quotas).

Most existing studies find a positive green WTP (Figure 1). However, estimates vary strongly between studies and products, ranging from 3%[3] to 22%[4,5] of the product price for electricity, from 0%[6] to 8%[7] for biofuels and from almost 0%[8,9] to 7%[10,11] for carbon offsets. Green WTP also varies between consumers. For most products, some consumers have a high green WTP, while others have an intermediate or low green WTP. Many consumers are also unwilling to pay any premium for green products. Shi et al.[12] provide a good illustration of this heterogeneity in green WTP for the case of renewable energy for 18 regions in 6 OECD-countries: In most regions, only a few consumers have a high green WTP of more than 15% of their electricity bill. Larger shares of consumers report intermediate (5-15%) or low (<5%) green WTP. However, in most regions, the largest fraction of consumers reports zero WTP for green electricity.[12] These heterogeneous green WTPs can be aggregated into a demand curve for the product's green attribute (green demand curve).

We further develop a stylized green demand curve (Figure 2). In a given market, its intersection with the supply curve of green products determines the green premium**Errore. L'origine riferimento non è stata trovata.**. As green production capacity increases for a given green demand curve, the green premium decreases because the product is sold to more consumers with a lower green WTP.

The challenge of uncertain green premia

The large variation in green WTP estimates translates into uncertainty about green demand curves and green premia. This increases with the forecasting horizon because future changes in consumer preferences might shift green demand curves, thus changing green premia in the market. Moreover, the difficulty in predicting future green production capacity further increases uncertainty. Thus, regulators only have a best guess of the development of the green premium and the corresponding necessary level of green public support programs to close the green profitability gap.

The unpredictability of green premia presents a challenge for designing green public support programs that aim to ensure continuous investment in green production processes. Based on an exemplary scenario, we further illustrate how uncertain green premia lead to uncertainty about the size of the green profitability gap that green public support programs aim to close (Figure 2). The declining incremental cost curve reflects the common assumption that future technological learning and increasing effective CO_2-prices will reduce incremental costs of green production. Notably, we ignore the uncertainty about future incremental cost developments because green public support programs can be indexed to the most important cost parameters, which can partly address this uncertainty (an example for indexing the support level to cost-parameters is the planned German pilot CCfD-program[13]).

Green public support programs with uncertain green premia

While there is considerable uncertainty surrounding the level and development of green premia, it is clear that only part of the population has a green WTP and that the green premium will decline (close) to zero once the share of green production exceeds the share of demand with a positive green WTP. Therefore, green premia alone will probably not be sufficient to fund the transition and green public support programs will likely be necessary until green production processes become cost-competitive. However, green premia can reduce the level of green public support programs needed and reduce transition costs.

Thus, green premia offer an opportunity to reduce costs of green public support programs if governments can solve the challenge of how to account for *ex-ante* uncertain green premia. The simplest option is to make green public support and green premia mutually exclusive by banning green marketing for volumes produced with green public support. However, prohibiting these low-emission products from being labelled as green would miss the opportunity to contribute to green lead markets. Instead there exist several alternative options for the responsive adjustment of green public support programs to green premia:

(i) **Pricing-in of green premia *ex-ante*:** Companies are allowed to keep the revenues from green premia. When the award mechanism for the green public support program is a competitive tender, companies will price in the expected value of the green premium in their bids, leading to lower support levels. However, since the risk associated with the green premium uncertainty resides with the companies, the latter will discount the green premium for the *ex-ante* uncertainty. Therefore, government support cannot be reduced by the full expected green premium. This option can be attractive if robust information about future green premia is *ex-ante* only available to firms but hard to access for the government (asymmetric information).

(ii) **Adjusting for green premia *ex-post*:** Companies are allowed to keep green premium revenues, but public support is adjusted *ex-post* by their value. This option can be attractive if there is high *ex-ante* uncertainty about the green premium for both the firms and the government and if it is easy to verify green premia *ex-post* (i.e., if transaction prices of comparable green and emission-intensive products are easily accessible or if a suitable indicator, such as a green price index, develops). However, green premia capture by the government reduces incentives to invest in marketing of the green attribute. Capturing only a portion of green premium revenues could mitigate this disincentive.

(iii) **Capturing green premia with green certificates:** In some power markets green certificates allow for a separate sale of the green attribute of electricity which allows consumers to verify clean procurement.[14] In principle, this could be extended to other green production processes. If a green production process obtains public support, the government would retain and separately auction the corresponding number of green certificates. Thereby, the government reduces support costs by recovering the green premium. However, this approach involves risks of perceived greenwashing and that producers from countries without green certificates redirect their readily available clean production volumes to countries using green certificates without actually changing their production processes (resource shuffling).

Policymakers will need to evaluate which option is best suited for their specific circumstances, considering the particular economic and policy context. If they succeed in adequately adjusting green public support programs to uncertain green premia, costs of climate action will be reduced, which possibly increases social acceptance of climate action.

Figure 1: Green WTP for different products (% of product price). *Figure 1 shows green WTP estimates from 24 studies (the complete list of references is available in the online supplementary material). We only considered studies that have been published in 2010 or later. To increase comparability of the estimates, we deflated WTP estimates to the year 2010, only selected studies that were conducted in OECD countries, and transformed (where necessary) absolute WTP estimates to relative WTP.*

Figure 2: Relationship between green demand, green premia and support levels
a) Green demand curve & different green premia for varying green production capacities. *Panel a) shows how the green demand curve and production capacity determine green premia. When green production capacity is low, the product is only sold to consumers with a high willingness to pay leading to a large green premium. As green production capacity increases, the product is sold to consumers with lower green WTP such that the green premium decreases. Eventually, when the green production capacity exceeds the share of the market with a positive green WTP, the green premium falls (close) to zero.*

__b) & c) Green profitability gap or necessary level of green public support with uncertain green premia.__ The green profitability gap or the necessary level of green public support programs (orange curve) is the difference between the incremental cost of green production (blue curve) and the green premium (green curve). Uncertainty about the green premium (green area) translates into uncertainty about the green profitability gap or the necessary level of green public support programs (orange area).

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AUTHOR CONTRIBUTION STATEMENT

All authors contributed extensively to the work presented in this comment. T.K. wrote the main text and created the figures. O.C., T.K., M.K., O.L., K.N., J.C.R. and X.S. were involved in conceptual discussions on the comment and reviewed and commented on the manuscript at all stages.

COMPETING INTERESTS STATEMENT

The authors declare no competing interests.

DATA AVAILABILITY STATEMENT

Source data, code and the complete list of references of Figure 1 is available under an open-source license (MIT) on Zenodo under the following DOI: 10.5281/zenodo.7848415.

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