Monopoly supply, technology leadership, and strategic trade policy in global climate policy*

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Abstract

This study considers the consequences of increased concentration of production of emission-reducing products for the incentives of individual countries to provide contributions to the global public good of reduced green-hous gas emissions. Analyzing the equilibrium repercussions in an interior private provision equilibrium it is shown that the existence of a monopoly supplier increases total emission reductions at the global level. The monopoly supplier country has an incentive to subsidize exports and benefits from this policy relative to a laissez-faire approach, whereas the effects on importer countries are ambiguous. From an ex-ante perspective, this creates an incentive for countries to invest in technology leadership or cost-reducing processes to obtain the monopoly supplier position.

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1 Introduction

Many countries are increasingly worried about their dependency on imports goods of such as solar panels, wind turbines, or electric vehicles which are pivotal in the green transformation and the further reduction of green-house gas (GHG) emissions from a single country, in particular China. According to the International Energy Agency China currently dominates the photolotaic industry. In 2021 its share in the world's manufacturing capacity in polysilicons amounted to 79.4%, in cells to 85.1%, in Modules to %74.7 and to 96.8% in wafers (IEA, 2022). Other countries such as Germany, which had important market shares in the photovoltaic industry 15-20 years ago, no longer have sizable market shares. In 2022, 87% of imported photovoltaic installations in Germany came from China (Mihm, 2023). This has raised fears that the leading producer country, i.e. China, could exploit its dominant position to the detriment of the importing countries, and that this could reduce the speed of the transformation to a carbon-free world economy.[1] In the shadow of such potential threats, the US have with the Inflation Reduction Act introduced large scale subsidies to reshore the production of such emission-reducing products. Similary, the European Union is discussing to weaken its rules on state aid in the common market to enable similar subsidies. The recently revealed draft of the European Union's Net-Zero Industry Act aims to increase the share of domestically produced green tech to 40% of the own climate and energy targets.

These heated political debates have led to the revival of a discussion of strategic trade policy issues such as international rent-shifting in non-competitive markets familiar since the 1980s. While the insights from the classic analyses, see Brander (1995) for an overview, remain valuable, the markets for green technology exhibit important characterics which need to be taken into account for sound policy evaluation. Emission-reducing goods are necessary for individual countries to engage in the reduction of GHG emissions. Moreover, these reductions by each individual country constitute private contributions to the global public good of GHG emission

[1]The concerns of Western dependence on Chinese manufacturers extend to other technological fields and products beyond the emission-reducing products, which are the topic of my analysis. Beyond purely economic aspects, they are also driven by political rivalry between China and the US. The objective of my study is to unveil the implications of monopoly supplier countries in markets where the products are instrumental in the provision of global public goods. This is why I abstract from such other aspects such as the resilience of supply chains.

reduction.

The current analysis breaks new ground by studying the effects of strategic trade policy of a monopoly supplier country of emission-reducing goods, where the equilibrium repercussions of such unilateral strategic trade policy are explicitly taken into account. My study introduces a monopoly supplier country in the standard private provision framework, and I show that the monopoly supplier country benefits from its monopoly position. However, contrary to standard market power arguments the monopoly country has no incentive to tax exports in order to increase the price of its export good on the world market. Surprising at first sight, it is optimal for the monopoly supplier to subsidize the exports of emission-reducing goods. However, my findings are rather intuitive in the light of extant key results in the literature on private provision of public goods. The loss in tax revenue from the subsidy of exports results in a transfer of income from the monopoly supplier country to the importer countries. As shown by Warr (1983) and Bergstrom et al. (1986), in an interior equilibrium such a transfer does not effect the equilibrium outcome, i.e. public and private good consumption by all parties remain unchanged, and thus does not make any country better or worse-off. At the same time, reduced prices for emission-reducing goods in the world market triggers higher emission reducing efforts by the importer countries, which increases total emission reductions. This benefits the monopoly supplier country, such that the total effect of subsidizing exports of emission-reducing goods makes the monopoly supplier better-off. This is reminiscent of the result by Buchholz and Konrad (1995) who show that transfers from less to high productive countries can make the former better off. Here, however, the strategic trade policy combines an income transfer with a price change for emission-reduction in the importing countries. The most important contribution of my work may be seen as pointing out the implications of these standard results for the optimal strategic trade policy of a monopoly supplier country.

The analysis also shows that the monopoly supplier country will typically be better-off than the importing countries. If the monopoly position is derived from an up-front investment in technology improvement, countries have an incentive to invest in order to achieve such a position.

Conceptually, my study is a variation of the classic private provision of public goods games as studied by Bergstrom et al. (1986), but connects the strategic trade literature with the literature on the private provision of public goods. This par-

allels Andres (2023), who studies in a different two-country, two-stage game with imperfect competition, differences in initial production cost, and learning-by-doing the production and consumption of an environmentally beneficial product in a. She focusses on the question of international trade agreements and argues that such agreements are most likely to be beneficial if production subsidies for clean technology are explicitly permitted.

2 The framework

There are $n+1$ countries $i = 0, 1, ..., n$. Countries have preferences $u^i(x^i, G)$, where x^i is private consumption and G are total global emission reductions which constitute a global public good. Both goods are assumed to be strictly normal. The total emission reductions are the sum of the emission reductions by individual countries g_i, i.e., $G = \sum_{i=0}^{n} g_i$. Countries are endowed with an exogenous income m^i.

My analysis departs from the usual assumption that countries have given, potentially different, productivity to reduce emissions. I make two key assumptions that determine the structure and the results in my model. First, emission reductions require the purchase of a particular good, and this good is only produced by the monopoly country. Thus, the price of emission reductions is not determined by the local technology, but by the price of the clean substitutes that enable to replace carbon-based consumption and production.

The seond key assumption is the determination of the price at which the emission-reducing good is available to individual countries in the world market. Country 0 is assumed to be the only producer of this good, possibly due to a leadership in technology or lower costs. The good is produced in a competitive industry in country 0, and its marginal cost of producing the good is constant and equal to c. Country 0 is called the monoply supplier or the market leader. All other countries rely on the products of the monopoly supplier to engage in emission reductions. Thus, set of countries is divided into the monopoly supplier country 0, and the remaining $j = 1, ..., n$ which need to import this good. Since all countries rely on the products of the market leader to engage in reductions the latter can effectively determine the price of emission reductions in all other countries p_j. This may be implemented by setting an appropriate tax or subsidy on the exports of the emission reducing

good. The price p_j is uniform across importer countries reflecting the fact that price discrimination will be difficult to establish given potential resale. The government of country 0 may also manipulate the domestic price of the good, and we call this price p_0.

My analysis proceeds as follows. I first consider a standard private provision game, see Bergstrom et al. (1986) for the seminal set-up and Buchholz and Sandler (2021) for a recent overview. My analysis differs from the standard analysis by introducing the monopoly supplier country. All other countries are assumed to rely on imports from the monopoly supplier to engage in emission-reducing activities.[2] The country-level monopoly allows this country to differentiate the price of engaging in emission-reducing activities between its domestic and the international market via appropriate export taxes and subsidies. Moreover, we assume that the private good x is internationally homogenous and that the international trade balance automatically adjusts.

After I have set up the private provision game and characterized for given international and domestic (in the monopoly supplier country) prices of the emission-reducing good, I proceed to investigate how the outcome in terms of totally provided quantity of the global public good and the equilibrium utility of the monopoly supplier and of the importer countries is affected by a systematic variation of the price.

Any of the symmetric importer countries $j = 1, ...n$ solves the standard private provision problem, see Bergstrom et al. (1986),

$$\begin{aligned} & \max \; u^j\left(x_j, G\right) \\ s.t. x_j + p_j G &\leq m_j + p_j G_{-j}, \\ G - G_{-j} &\geq 0, \\ x_j &\geq 0, \end{aligned}$$

where $G_{-j} = \sum_{i=0, i\neq j}^{n} g_i$ is the total emission reduction by all other countries, including the emission reduction by the technology leader and monopolist, country 0. The solution to this problem implicitly yields the best responses of the importer countries.

The technology leader solves an analoguous problem. However, the technology

[2]Wile there may be a domestic alternative technology, i.e. costlier or less advanced solar panels etc. the domestic alternative is assumed to be irrelevant due to its substantial cost-efficiency disadvantage.

leader not only has exogenous income m_0, but also receives potential tax revenues and profits from the monopoly Π_0. The profits are $\Pi_0 = (p_0 - c)\, g_0 + (p_j - c)\, G_{-0}$, where G_{-0} are the combined emission reductions by all other countries. We can thus express the budget constraint of the technology leader as

$$\begin{aligned} x_0 + p_0 g_0 &\leq m_0 + \Pi_0 = m_0 + (p_0 - c)\, g_0 + (p_j - c)\, G_{-0} \\ x_0 &\leq m_0 - c g_0 + (p_j - c)\, G_{-0} \\ x_0 + cG &\leq m_0 + (p_j - c)\, G_{-0} + cG_{-0} = m_0 + p_j G_{-0}. \end{aligned}$$

This shows that the domestic price in the market leader country drops out of its budget constraint and is therefore irrelevant for the actual decision problem. The relevant price for this country are the marginal costs of the emission-reducing good. The optimization problem of the technology leader is thus

$$\begin{aligned} & \max_{x_0, G} \; u^0\,(x_0, G) \\ s.t.\; x_0 + cG &\leq m_0 + p_j G_{-0}, \\ G - G_{-j} &\geq 0, \\ x_0 &\geq 0. \end{aligned}$$

The solution to this problem yields the monopoly suppliers best response, which together with the importer countries' best responses determine the equilibrium outcome.

For the further analysis it is convenient to rely on an aggregate game approach, similar to Buchholz and Sandler (2021). This allows straightforward investigation of the equilibrium repercussions of changes in the export price of emission-reducing goods.

For an importer country the price of one unit of g is p_j. Thus, $x_j = m_j - p_j g_j$, so that $g_j = \frac{1}{p_j}\,(m_j - x_j) = a_j\,(m_j - x_j)$, with $a_j \equiv 1/p_j$. Any feasible equilibrium allocation has to satisfy

$$G = n g_j + g_0 = n a_j\,(m_j - x_j) + a_0\,(m_0 + \Pi_0^e - x_0)$$

where $\Pi_0^e = (p_j - c)\, G_{-0}$ is the monopoly supplier's rent from exporting the emission-reducing good and $a_0 = 1/c$ denotes the productivity parameter for monopoly supplier. This can be manipulated to yield

$$G = n a_0\,(m_j - x_j) + a_0\,(m_0 - x_0)\,.$$

Now, let $e(G, \alpha_i)$ be country i's income expansion path which maps the totally provided quantity of the public good into private consumption, where α_i denotes the marginal rate of substitution between the private and the public good, i.e., $\alpha_i = \frac{\partial u^i/\partial G}{\partial u^i/\partial x_i}$. Due to non-inferiority of both goods the expansion paths are strictly increasing in G.

At a Nash equilibrium, in which all countries contribute we must have for each country that $\alpha_i = a_j$. For country 0, which posesses the technology monopoly we have $a_0 = 1/c$, for all other countries $a_j = 1/p_j$. Thus, at any interior Nash equilibrium $(x_0, ..., x_n, G)$ all countries i will be on their respective expansion pathes $e^i(G, a_i)$. The condition for an interior Nash equilibrium can then be written as

$$G = na_0 \left[m_j - e^j(G, a_j)\right] + a_0 \left[m_0 - e^0(G, a_0)\right].$$

This allows to assess how the equilibrium quantity G changes as we change a_j. Differentiating of the above yields

$$G'(a_j) = -na_0 \left[e^j_G G'(a_j) + e^j_{a_j}\right] - a_0 e^0_G G'(a_j),$$

which implies

$$G'(a_j) = \frac{-na_0 e^j_{a_j}}{1 + na_0 e^j_G + a_0 e^0_G} > 0.$$

The sign follows from the positive slope of the expansion pathes, so that $e^j_G > 0$ and $e^0_{a_j} > 0$, and from the fact that normality implies $e^j_{a_j} < 0$, i.e. a decrease in the price of the emission-reducing good, which increases a_j, reduces the consumption of the private good. I state this as my first proposition.

Proposition 1 *At an interior Nash equilibrium an increase in the price charged by the monopoly supplier leads to a reduction in total public good provision.*

The intuition of the result is straightforward. An increase in the monopoly supplier's price has two effects. First, it generates an income transfer from the importer countries to the monopoly supplier. Warr (1983) has demonstrated that at an interior equilibrium such a transfer does not change the totally provided quantity of the public good. Second, the price increase makes contributions to the public good more expensive for all importer countries. This unambigously reduces their contributions so that the total quantity of the public good is reduced. This relates to the literature on technology transfers in private provision games, i.e. the fact

that it may be advantageous to improve other countries technological capabilities. It also relates to the benefits of transferring resources to countries which are more efficient in reducing emissions, see Buchholz and Konrad (1995) and Ihori (1996), among others.

We can now consider what happens to the equilibrium utility of the monopoly supplier country as it manipulates the price of the emission-reducing good p_j. The equilibrium utility achieved by the monopoly supplier is $u^{0^*} = u\left(e^0\left(a_0, G\left(a_j\right)\right), G\left(a_j\right)\right)$, so that

$$\frac{\partial u^{0^*}}{\partial a_j} = u_x e^0_G G' + u_G G' = G'\left[u_x e^0_G + u_G\right] > 0.$$

This im my next result.

Proposition 2 *The utility of the monopoly supplier in an interior equilibrium is decreasing in the price charged by the monopoly supplier. The optimal policy of the monopoly supplier is to subsidize its exports of emission-reducing goods.*

This implies that the monopoly supplier even has an incentive to subsidize the emission-reducing good. In sharp contrast to a monopoly situation in markets for private goods, where the monopoly supplier country has an incentive to tax exports and to reduce supply in order to extract monopoly profits from the rest of the world, here the monopoly supplier has incentives to reduce prices. Moreover, this countries will even subsidize exports below marginal costs as long as the equilibrium is an interior equilibrium. The intuition is again straightforward and relates to the two effects of changing the price of the emission-reducing good. While a reduction in the price leads to an income transfer from the monopoly supplier to the importer countries, this does not hurt the monopoly supplier. First, the income transfer will be offset one-to-one by a reduction in the contribution of the monopoly supplier country, which will be fully compensated by the contributions of the importer countries which receive the income transfer. This income transfer is fully neutral. However, as we have seen from proposition 1, a price reduction increases the equilibrium quantity of the public good, which benefits the supplier country.

Consider now the utility of an importer country at an interior equilibrium. It is given by $u^*_j = u\left(e^j\left(a_j, G\left(a_j\right)\right), G\left(a_j\right)\right)$, so that

$$\frac{\partial u^*_j}{\partial a_j} = u_x\left(e^j_{a_j} + e^j_G G'\right) + u_G G'$$

In general, the sign of this expression is ambiguous. While the second term is positive, the first term is undetermined. The second term is the direct effect on utility from of marginally increased total public goods, which is evaluated by the marginal utility of public goods. This term is unambigously positive for an increase in a_j (a decrease in p_j). The first term consists of two elements. The first element is the response to relative prices. An increase in a_j corresponds to a decrease in p_j which triggers higher contributions g_j and lower private consumption x_j. Thus, this element is negative. The second element is the increase in private consumption due to the income effect generated by the increased level of total public goods supply. This term is positive. Both elements are evaluated by the marginal utility of private consumption. Thus, the total effect of the first term is undetermined, such that also the combined effect is undecided.

While it is in general not clear, whether the monopoly supplier will always be better-off relative to an importing country with an export subsidy on the emission-reducing good, at the benchmark where with identical incomes and an original price $p_j = c$ this will be the case for a marginal subsidy. I summarize this in my next proposition.

Proposition 3 *(i) Whether the utility of the importing countries in an interior equilibrium increases or decreases in response to a marginal decrease in the price p_j is ambiguous. (ii) Starting from the benchmark with the same exogenous incomes and no tax/subsidy intervention, such that $p_j = c$ a marginal decrease in p_j will benefit the monopoly supplier more than the importing countries.*

3 Investment and technology leadership

The extant literature on incentives to invest in technology improvements has stressed the strategic dilemma that countries face if upgrading their technoligical capabilities to reduce GHG emissions. Buchholz and Konrad (1994) where the first to show that even for completely costless technogy, countries may not be better off by adopting such more efficient technology. That global climate agreements face the challenge that there are two global public goods that need to be provided, emission reductions and technological innovations, has also be stressed by Barrett (2006). Similarly, Harstad et al. (2019) study the interaction between technology investment and contributions in a dynamic setting. Within the classic static private provision

framework similar to my setting Buchholz et al. (2015) study coalition formation to invest in technology improvements, which may spill-over to other countries. My analysis differs from most other studies in that technology is not locally given, or spills-over automatically, but it is embodied in the products of the monopoly supplier country.

Proposition 3 suggests that the monopoly supplier is typically better off than the importer countries. Under the assumption that the monopoly position of country 0 is due to its technology leadership or more efficient production, and that this leadership is generated by ex ante investments, we see that this generates incentives for countries to invest in technology improvements to become the monopoly supplier. Thus, the outlook for investments in technology upgrades may not be as bleak as in the benchmark model without the emergence of market power at the country level.

4 Conclusion

A monopoly supplier country of emission-reducing goods has an incentive to engage in strategic trade policy. The optimal policy for this country is not to exploit its market power to increase the world market price of its exports. To the contrary, the optimal strategic trade policy is to subsidize these exports. This leads to lower own contributions to the global public good. However, these are overcompensated by the increased contributions of the importer countries which face lower prices. The latter must not necessarily loose from the strategic trade policy, but whether it is actually gains from the cheaper prices it faces remains ambiguous.

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