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Abstract

We analyze self- and joint procurement of countries with heterogeneous demand for a good offered by a price discriminating monopolist. We find that not only countries with low but also with high demand can benefit from committing to jointly procure equal quantities at a uniform price, even if the supplier is capacity constrained. Free-riding of outside buyers as well as too much heterogeneity of insiders make the buyer group unstable. Uniform price procurement without a quantity restriction is only stable with intra-group transfers. We relate our findings to the COVID-19 vaccine procurement of the European Union.

JEL classification: C79, D42, L12.
Keywords: joint procurement, group purchase, heterogeneous buyer group, vaccine procurement, price discrimination.

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1 Introduction

Until the end of the year 2021 the European Commission (EC) procured more than four billion doses of COVID-19 vaccines on behalf of 27 member states of the European Union (EU).[1] The procurement strategy comprised central actions such as negotiations with pharmaceutical firms about contracting in advance to product release, allocation decisions, i.e. the number of vaccine doses and uniform prices.[2] To fairly distribute the scarce vaccine, the EC restricted the members states to purchase a quantity of vaccines that was calculated according to their respective population share in the EU.[3] The EC described this approach as being the "surest, quickest and most efficient way"[4] to secure inoculations in the COVID-19 pandemic for its member states that are heterogeneous in factors such as population size, GDP, and preferences. Various commentators criticized the joint procurement, especially because of the perceived lack of quantities in the early delivery phases.[5]

Besides vaccines, the EU applies and intends to apply joint procurement strategies in other fields. In the course of the pandemic the EU procured other medical countermeasures in the amount of €13 billion such as protective equipment for 36 countries in 12 joint procurement procedures.[6] In 2021 the EC released a proposal to jointly procure gas reserves for participating members states.[7] A new proposal of the EU even includes a commitment for member states to procure a certain amount of their gas jointly at a uniform price to prevent intense competition between members and therefore, high prices. The proposal is the result of negotiations of the member states that had different opinions on various issues, such as the usefulness of a price cap that could possibly result in reduced supply. [8]

The above examples highlight conflicting interests between richer and poorer countries when procuring jointly at a uniform price. For instance, rich countries may fear that a lower uniform price results in quantities that are too low while poor countries may fear paying too much when facing the same price as rich countries. Moreover, it is unclear how effectively joint procurement can increase buyer power when there are buyers outside the buyer group and supply is limited. In this context, if joint procurement lowers the demand from the buyer group, this may be compensated by higher quantities delivered to outsiders. We investigate these issues and consider how joint procurement affects the quantities and surpluses of the different buyers and whether a buyer group is stable.

[1] See European Commission "Safe COVID-19 vaccines for Europeans", last accessed 13.12.2021.

[2] See European Commission"EU Vaccines Strategy", last accessed December 2021.

[3] Members states could buy more if other members did not make use of their purchase options.

[4] European Union "Council Regulation (EU) 2020/521 of 14 April 2020 activating the emergency support under Regulation (EU) 2016/369, and amending its provisions taking into account the COVID-19 outbreak", Official Journal of the European Union, ST/7169/2020/INIT, 2020, last accessed December 2021.

[5] See Eurotopics "Vaccines for the EU: too little, too late, too cheap?", 2021, last accessed August 2022.

[6] See European Commission "Ensuring the availability of supplies and equipment", 2022, last accessed August 2022.

[7] See European Commission "Commission proposes new EU framework to decarbonise gas markets, promote hydrogen and reduce methane emissions", 2021, last accessed January 2022.

[8] See European Commission "Commission makes additional proposals to fight high energy prices and ensure security of supply", 2022, and Frankfurter Allgemeine Zeitung "Ein Gaspreisdeckel gegen Deutschland", 2022, last accessed November 2022.

We set up a model to compare outcomes for countries which differ in their demand and use self- or joint procurement strategies facing a monopolistic supplier. To approximate a capacity constraint production for a scarce good, such as COVID-19 vaccines in early 2021, we consider (weakly) increasing marginal costs of the supplier. We consider a continuum of countries with either a low or a high demand. We refer to them as *poor* and *rich* countries. Shares of both types of countries form a buyer group and procure jointly, while the other countries rely on self-procurement. These countries represent the rest of the world. We compare three procurement rules. In the benchmark case of self-procurement, we allow the monopolist to charge different prices to different countries. This results in third degree price discrimination based on the countries' willingness to pay. The first joint procurement rule requires the supplier to charge countries in the buyer group a uniform price. The second joint procurement rule contains the uniform price requirement and, in addition, requires that rich countries cannot buy more on a per-capita basis than poor countries. The latter rule relates to a joint procurement strategy where a buyer group purchases goods in predefined amounts at low prices for its members, like in the vaccine purchase of the EU.

Under joint procurement with uniform pricing, the supplier charges countries in the buyer group a uniform price that is above the price that poor countries receive under self-procurement and below the corresponding price of rich countries. Compared to price discrimination, this procurement rule is not a Pareto improvement for the group members as poor members are worse off. Interestingly, the surplus increase of rich members can outweigh the loss of poor members. The reason is that the additional consumption in the rich country as a result of the lower price there has a higher value – in terms of willingness to pay derived from the inverse demand function – than the lost consumption in the poor country as a result of a higher price there. To the extent that transfers between rich and poor member countries are feasible and acceptable, the buyer group can thus collectively benefit from uniform price procurement relative to self-procurement.

Joint procurement with both a uniform price and quantity restriction can instead benefit both poor and rich member countries even absent any transfers compared to self-procurement as well as joint procurement with a uniform price only. The reason for this is that the uniform quantity restriction implies that rich member countries cannot buy as much as they would under self-procurement with increasing marginal costs. The reduced demand of rich group members induces the supplier to charge a lower uniform price to the group than it would without a quantity restriction. This is a *monopsony effect.* The uniform price is even lower than the price of poor members under self-procurement. The reason is that the demand reduction of rich group members put the supplier on a lower point of its marginal cost curve, which leads to lower optimal prices. The more rich countries join the buyer group, the stronger this effect becomes. If, instead, the demand of rich and poor members differs too much, the quantity restriction hurts rich members and outweighs the benefit of a lower price for them. In this case, the previously discussed joint procurement rule with uniform pricing and no quantity restriction yields the largest sum of surpluses of the members of the buyer group.

Joint procurement of the buyer group can affect non-member countries in the case of increasing marginal costs. To the extent that joint procurement leads to a different

aggregate demand of the buyer group, the supplier is on a different point of its marginal cost curve when serving the rest of the world. As the quantity restricted joint procurement of the group decreases the group's total demand, it puts the supplier on a lower point of its marginal cost curve. This leads to lower discriminatory prices for both poor and rich non-members. We refer to this as a *free-riding effect*. Rich countries becoming part of the buyer group exert a positive externality on outsiders, so that staying outside can be preferable for rich countries. At least with linear demand, joint procurement that only requires a uniform price has no effect on aggregate demand and thus leaves the rest of the world unaffected.

We also discuss the stability of the buyer group by answering the question whether member countries obtain a lower surplus than non-member countries under certain conditions and, therefore, have an incentive to leave the group. We first consider the case where compensation with transfers between members is not possible. A buyer group is in this case not stable under uniform price procurement because poor members are better-off outside the group due to the lower discriminating price. Under uniform quantity procurement, poor members have no incentives to leave the group. Rich countries strictly benefit from being members with constant marginal costs and if the heterogeneity in demand between rich and poor members is not too high and if the share of rich countries that are members of the group is large enough with increasing marginal costs. Otherwise rich non-members obtain a higher surplus than rich members. The reason for this is an over-commitment of rich members to too low quantities given their demand. The buyer group is not stable in this case.

Stability is higher if transfers are feasible and group members that benefit from the joint procurement can compensate members that lose. A buyer group is stable under uniform pricing if rich members compensate poor members, provided that poor members buy a positive quantity at the average uniform price. Under uniform quantity procurement, poor members, who are indifferent between joining the group or not, cannot compensate rich members that lose as this would violate their own participation constraint. Under this procurement rule, a buyer group may be stable without transfers but, if not, transfers do not increase stability.

In summary, poor member countries tend to benefit when rich members of the buyer group get only as much quantity as poor members. With increasing marginal costs, they gain from the lower quantity that the rich members can purchase and the therefore lower prices. For rich members, both forms of joint procurement can be favorable, depending on the degree of heterogeneity of the group and the composition of the buyer group.

Our article has the following structure. Section 2 relates to the literature. Section 3 sets up the model. Section 4 contains the results of the subgames for the different procurement rules and a given group composition. In Section 5 we discuss the optimal procurement choice of the buyer group and in Section 6 the stability of a buyer group. In Section 7 we relate our model to the case of the COVID-19 vaccines and the EU. Thereby, we review stylized facts and assessments of economists about the joint procurement and link them to the results of our model framework. We conclude in Section 8.

2 Related literature

We relate to the literatures on price discrimination, group purchase in industrial economics as well as joint vaccine procurements.

Price discrimination. Armstrong (2006) reviews several forms of price discrimination and analyzes their impacts for consumers. He compares market outcomes in a setup where a firm can either price discriminate between markets that differ in their share of high and low valuation consumers or set a uniform price for both markets. The uniform price can be higher than the discriminating price for the market with more low valuation consumers. This harms consumers in that market while consumers in the market with more high valuation consumers gain.

Our article relates to this literature by applying procurement rules for heterogeneous countries in the form of third degree price discrimination and a uniform price setting. We interpret the first as a from of self-procurement and the second as a form of joint procurement. Different from the literature, we consider the presence of outsiders to the buyer group and thus analyze an intermediate case between price discrimination and uniform pricing. Our result that uniform pricing increases the surplus of rich countries and reduces the surplus of poor countries in the buyer group extends the findings of this literature to this intermediate setting. In addition, the novel case with a uniform quantity restriction highlights that both poor and rich buyers can be better off under uniform pricing than under price discrimination if rich buyers commit to limit their demand.

Group purchase and joint procurements. Joint procurement – also referred to group purchase and pooled procurement – [9] has been documented for industries, retailing, health care as well as the public sector (Essig (2000), Nollet and Beaulieu (2003)). Tella and Virolainen (2005) and Schotanus (2005) show empirically that group purchase in the industrial sector or by institutions leads to various benefits, such as cost reductions due to lower transaction costs, lower prices and an increase in information exchange.

In the theoretical literature, a starting point is the insight that a decrease in the number of competing downstream firms may or may not increase their Nash bargaining position vis-a-vis a supplier, depending on the type of downstream competition (von Ungern-Sternberg (1996), Dobson and Waterson (1997)). The effect on the equilibrium wholesale price is thus ambiguous. The literature also studies group purchase of heterogeneous buyers more specifically (Li (2012), Marvel and Yang (2008), ...). This strand of literature focuses on joint procurement at a uniform price and its effects on the market outcome when sellers and / or buyers compete. They do not consider uniform quantity procurement and abstract from outsiders that are not part of the buyer group. Some articles focus on supplier competition. Li (2012) considers Nash bargaining over the price in a setting with two competing sellers and two competing buyers. The buyers differ in their preferences towards the differentiated sellers. She finds that it is beneficial to buy jointly if the relative bargaining power of the group vis-a-vis the suppliers is high and the degree of

[9] There are different terms in use to describe the consumer purchase strategy of an aggregation of demand. The term group purchase is mainly used in the private sector, joint or pooled procurements often refer to the public sector. We use the terms synonymously.

heterogeneity among the group members is large.

Marvel and Yang (2008) consider two suppliers that compete for consumers that are distributed on a Hotelling line. They show that, against the benchmark of competition in simple linear prices, the feasibility of all buyers to require the sellers to make collective two-part tariff offers reduces prices. The buyers benefit if their preferences of the buyers are not too asymmetric (that means the transport costs on the Hotelling line need to be small enough). As in Li (2012) a lower price results from intensified supplier competition whereas we obtain our results in a setting with a monopoly supplier. A similarity is that the heterogeneity of buyers is relevant for the outcome of joint procurements.

Chen and Roma (2011) consider two competing retailer who purchase a good from a monopoly supplier that charges uniform prices and is assumed to grant quantity discounts. They find that group purchase is beneficial for symmetric retailers. For asymmetric retailers the weaker retailer still gains from buying jointly due to the reduced competition, while the stronger retailer might not due to the diminishing effect of the competitive advantage under group purchase.

Chen and Li (2013) and Dana Jr (2012). find that the commitment to buy jointly exclusively from one supplier fosters competition among suppliers to capture the whole demand and leads to lower prices. Dana Jr (2012) show that this may result even for small buyer groups whereas Chen and Li (2013) demonstrate that exclusivity commitment leads to less product variety. Chae and Heidhues (2004) show that it can be favorable for risk-avers buyers to buy jointly because it allows them to share related risks.

In contrast to these articles, we focus on purchases of a scarce product in a context where a heterogeneous buyer uses, inter alia, a quantity restricted form of joint procurement and faces competition on the demand side from other buyers.

Vaccine procurement. Case studies about joint vaccine procurements confirm the above stated benefits of group purchase such as lower prices (DeRoeck *et al.* (2006)). They furthermore reveal that lower income countries benefit in particular from the more affordable prices, equal allocations and ensured supplies compared to self-procurements. The World Health Organization reports that country-specific and worldwide vaccine prices of 2019 were significantly different for joint and self-procurements; for middle income countries the prices were 60% lower in the case of joint purchases.[10] Unfavorable conditions for joint vaccine procurements are if group participants are rather heterogeneous, for instance concerning product preferences or income, and unpredictable, very specific or low demands of the group members.[11] The policy paper by Ahuja *et al.* (2021) analyzes risk sharing between producers and buyers as well as incentives for speed when building up production capacity for COVID-19 vaccines. They argue that high income countries have less incentives to join a centralized procurement with cross subsidization. Athey *et al.* (2022) emphasize as well that participation in a mechanism like the worldwide initiative COVID-19 Vaccines Global Access (COVAX) is particular questionable for high income countries as they would prefer bilateral contracts. This contrasts with our findings

[10] World Health Organization "Global Vaccine Market Report", December 2020 , last accessed December 2021.

[11] See William Davidson Institute "Pooled Procurement in the Vaccine Market: UNICEF's Experience", December 2015, last accessed December 2021.

that rich countries can benefit from joint procurement at a uniform price even if they restrict their purchases. It is noteworthy that Kessing and Nuscheler (2006) examine external effects of vaccination in a setup where a price discriminating monopolist faces a heterogeneous demand. We abstract from considering specific externalities of vaccination in our analysis of joint procurement.

3 Model setup

Supply. The profit-maximizing monopoly supplier produces a private good (no consumption externalities) and has a weakly convex cost function of

$$C(Q) = \kappa \cdot Q^2,$$

where Q is the total quantity produced. The parameter κ, with $\kappa \in \{0, 1\}$, defines whether the marginal costs are constant (and normalized to zero) or increasing.

Demand. On the demand side, there is a mass one of atomistic countries with a low willingness to pay (WTP), what we refer to as *poor* countries and a mass one of atomistic countries with a high WTP, what we refer to as *rich* countries, denoted by the index $i \in L, H$.

The demand of a country at a price p is

$$d_i(p) = \max\left(1 - \frac{1}{\gamma_i} \cdot p, 0\right), \tag{1}$$

where the parameter γ_i captures the willingness to pay. The larger the parameter the weaker the decrease of the purchased quantity with an increase in price, $(\partial d_i(p)/\partial p = -\frac{1}{\gamma_i} < 0)$. For simplicity, we set $\gamma_H = 1$ and assume $0 < \gamma_L < 1$. The larger γ_L, the more similar the countries are. We assume that demands are weakly positive.

Each country maximizes the surplus obtainable with the demand function d_i for a given price. Absent a buyer group and faced with a price of p, this implies that each country of type i buys a quantity of $d_i(p)$. This yields a total demand of

$$Q = 1 \cdot d_L(p) + 1 \cdot d_H(p).$$

We exclude arbitrage between countries, even when they are members of a buyer group.

Buyer group. The share $l \in (0, 1]$ denotes the mass of poor countries that are members of the buyer group, whereas $h \in (0, 1]$ denotes the respective mass of rich group members. The buyer group commits to a procurement rule which may restrict the supplier in its price setting and the group members in the quantities that they are allowed to buy. The non-member countries procure in any case individually, i.e. the share of $1 - l$ of poor countries and the share of $1 - h$ of rich countries. We refer to non-member countries as the rest of the world (ROW).

Suppose the buyer group's procurement rule implies that a member country of type i buys a quantity of q_{iG}. This yields total demand of

$$Q = \underbrace{l \cdot q_{LG} + h \cdot q_{HG}}_{\text{demand buyer group}} + \underbrace{(1-l) \cdot d_L + (1-h) \cdot d_H}_{\text{demand rest of the world}}. \tag{2}$$

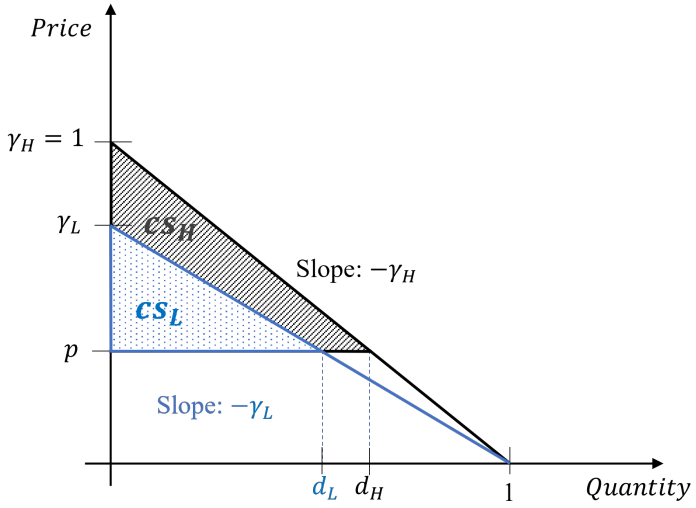

Figure 1: Demand functions and consumer surplus of poor and rich countries absent a buyer group.

Procurement rules. We focus on the following procurement rules:

1. **Price discrimination and no quantity restriction (PD).** This is the benchmark of effectively no joint procurement where the supplier charges each country a price in view of the country's demand function.

   - Mechanism: This procurement rule may result even if there is a buyer group which has a more sophisticated procurement mechanism but cannot force its members to buy exclusively (or at least to a large enough degree) through the group's mechanism.

2. **Uniform price and no quantity restriction (UP).** The buyer group requires that the supplier charges each member the same price p_G independent of its willingness to pay. Each member country buys the quantity that maximizes its surplus at this price, that is $q_{iG} = d_i(p_G)$. The supplier can still charge non-members prices p_i depending on their willingness to pay as above, yielding demands of $d_i(p_i)$.

   - Mechanism: While the supplier can price discriminate, the buyer group is able to enforce a uniform price. One can think of a joint buying mechanism of the buying group that results in this outcome: The buyer group only purchases all quantities jointly for a single price. Members are not allowed to purchase outside the buying mechanism. After the supplier announces the prices, each country submits the quantity it wants to buy at this price to the buyer group which then purchases the aggregate quantity. Each country optimally submits the quantity it actually wants to purchase given its demand function. Hence,

the supplier is forced to offer a single price to the buyer group and faces the aggregate demand of the group.

3. **Uniform price and uniform quantity (UQ).** The buyer group requires a uniform prices as in the previous case. In addition, it requires that each member country gets the same quantity: $q_{LG} = q_{HG}$ (due to the assumption of equally sized atomistic countries, this holds per capita as well) that we denote as q_G. The supplier can still charge non-members prices p_i depending on their willingness to pay as above, yielding demands of $d_i(p_i)$.

   - Mechanism: As before, members of the buyer group purchase all quantities jointly for a single price p_G and no purchasing is allowed outside of the buying mechanism. After the supplier announces its prices, each member country submits the quantity it wants to purchase at this price to the buyer group. The mechanism restricts each member to buy no more than the minimum of the quantities submitted by all members. Hence, each member country buys the same quantity. Given the firm's price for the group and the group's mechanism, it is individually rational and optimal for each country to submit to the group the quantity it wants to buy given its demand function. This implies that the quantity for each member country equals $q_G = d_L(p_G)$. The mechanism boils down to the supplier charging a single price to all countries in the buyer group and the quantity demanded by each country being the demand of the country with the lowest willingness to pay, i.e., the lowest γ_i within the buyer group.Figure 2 provides an overview of the three procurement rules.

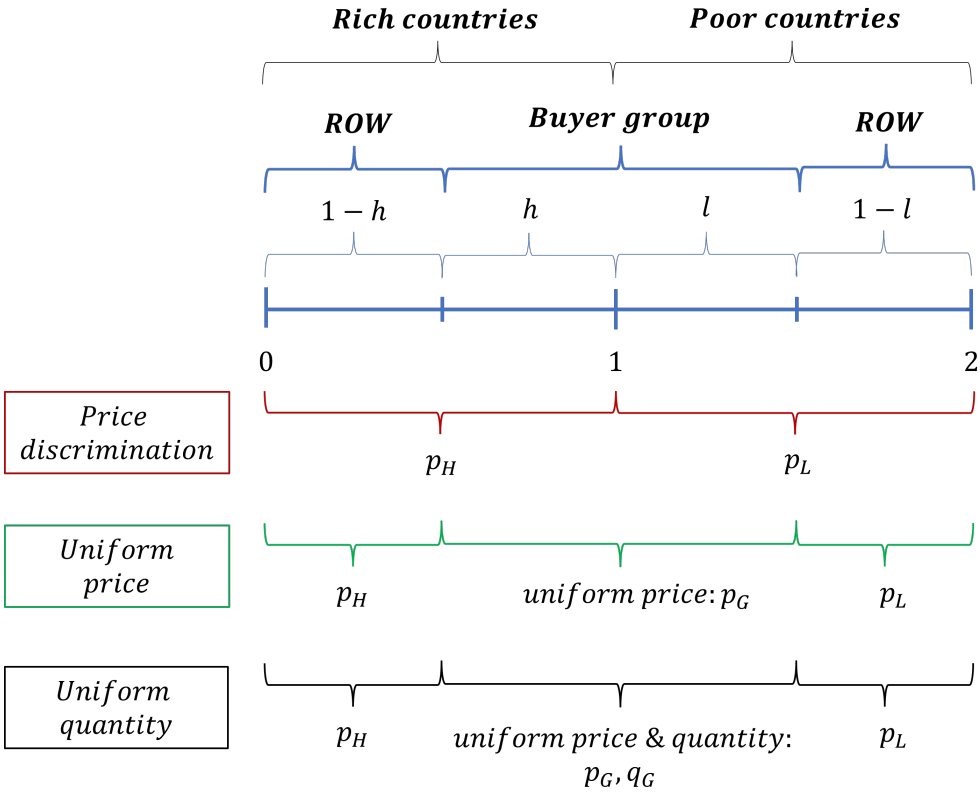

Figure 2: Procurement rules.

Assumption 1. *γ_L is sufficiently large such that under price discrimination poor countries buy strictly positive quantities.*

This holds for $\gamma_L > 0$ for constant marginal costs and for $\gamma_L > \frac{1}{2}$ for increasing marginal costs (we derive these thresholds in the context of Lemma 1).

Timing and solution concept. For a given procurement rule and buyer group composition l and h, the timing of the sales game is as follows:

1. The supplier sets prices p_i for non-member countries type $i \in \{L, H\}$ and price p_G for member countries, subject to the buyer group's procurement rule.
2. The countries make their purchasing decisions: Non-member countries choose their quantities individually according to their demand d_i and the member countries choose their quantities q_{iG} according to the procurement rule.

We solve this game of complete information for subgame perfect Nash Equilibria (SPNE). The next section presents the equilibria of the sales game for each procurement rule and a given composition of the buyer group. We study how the buyer group chooses its procurement rule in Section 5 and consider the stability of the buyer group in Section 6.

Supplier profit. The firm's profit is

$$\pi(p_i, p_G) = \underbrace{l \cdot q_{LG} \cdot p_G + h \cdot q_{HG} \cdot p_G}_{\text{revenues buyer group}} + \underbrace{(1-l) \cdot d_L \cdot p_L + (1-h) \cdot d_H \cdot p_H}_{\text{revenues rest of the world}} - C(Q), \quad (3)$$

with $C(Q) = \kappa \cdot Q^2$ as defined above.

Consumer surplus and total welfare. If a country faces a price p and obtains the quantity $d_i(p)$ which it demands at this price, its consumer surplus equals the area between the inverse demand and the price (see Figure 1). This is always the case for non-member countries whose consumer surplus we denote by

$$cs_i(p) = \frac{1}{2}\left((\gamma_i - p) \cdot d_i(p)\right). \quad (4)$$

The same holds for all member countries under price discrimination (PD) and uniform pricing (UP) at the corresponding prices $p_i, i \in \{L, H\}$ and p_G. It also holds for poor member countries under uniform quantity procurement (UQ) whereas rich countries are restricted to buy the quantity $q_G = d_L(p_G)$ in this case, which is below their demand $q_{HG} = d_H(p_G)$. For this case we assume that the rich countries maximize their surplus by serving demands with a high valuation first. This corresponds to efficient rationing within the country. See Figure 3 in Appendix I. We can thus write the consumer surplus of an (atomistic) country $i \in \{L, H\}$ of the buyer group obtaining a quantity q at a price of p as

$$cs_{iG}(p, q) = \begin{cases} cs_i(p) & if\ q = d_i(p), \\ \frac{1}{2}\left((\gamma_i - p) \cdot d_i(p)\right) - \frac{1}{2}\left((d_i^{-1}(q) - p) \cdot (d_i(p) - q)\right) & if\ q < d_i(p), \end{cases} \quad (5)$$

where $d_i^{-1}(q)$ denotes the inverse demand function, that is the price that a country i would pay to purchase the quantity q without the uniform price. We refer to Equations (5) and (4) as country-specific consumer surpluses.
The aggregate consumer surplus of the buyer group is the sum of the country-specific consumer surpluses (Equation (5)) of all member countries:

$$CS_{Group} = l \cdot cs_{LG} + h \cdot cs_{HG}. \tag{6}$$

The aggregate consumer surplus of all countries is therefore

$$CS_{World} = l \cdot cs_{LG} + (1-l) \cdot cs_L + h \cdot cs_{HG} + (1-h) \cdot cs_H. \tag{7}$$

These are the key figures to assess the procurement rules from the individual and aggregate consumer perspective of heterogeneous countries.

Furthermore, total surplus is the sum of producer (i.e., profits) and consumer surplus:

$$W = \pi + CS_{World}. \tag{8}$$

4 Pricing outcomes

4.1 Price discrimination and no quantity restriction (PD)

This is the benchmark where membership in the buyer group has no effects on the market outcome, such that the solution is independent of l and h. We start with solving the equilibrium of the continuation game starting in stage 2. In stage 2, each country observes the price p_i that the supplier charges to a country of type i. Each country chooses the quantity $d_i(p_i)$ that maximizes its surplus. This yields a total demand of $Q(p_L, p_H) = d_L(p_L) + d_H(p_H)$. In stage 1, the supplier sets different prices for the two country types to maximize its profits:

$$\max_{p_H, p_L} \pi = p_H \cdot d_H(p_H) + p_L \cdot d_L(p_L) - C\left(Q\right) \tag{9}$$

with $C(Q) = \kappa \cdot (d_L + d_H)^2$. Differentiation yields the first order conditions (focs)

$$\frac{\partial \pi}{\partial p_H} = d_H(p_H) + p_H \frac{\partial d_H(p_H)}{\partial p_H} - \frac{\partial C(Q)}{\partial Q} \frac{\partial d_H(p_H)}{\partial p_H} = 0, \tag{10}$$

$$\frac{\partial \pi}{\partial p_L} = d_L(p_L) + p_L \frac{\partial d_L(p_L)}{\partial p_L} - \frac{\partial C(Q)}{\partial Q} \frac{\partial d_L(p_L)}{\partial p_L} = 0. \tag{11}$$

For constant marginal costs ($\kappa = 0$), the last term of Equations (10) and (11) vanishes. Therefore, the equations are independent, i.e., the optimal price of the one country type does not depend on the demand of the other country type. The constraint that demand has to be non-negative does not bind.[12]

[12]To see that d_i must be positive consider, for example, Equation (10). Note that the last term in Equation (10) is zero, the second last term is negative by assumption. Thus, the first term, the demanded quantity, has to be positive such that the foc holds. The same holds for Equation (11).

For increasing marginal costs ($\kappa = 1$), the price of one country type depends on the demand of the other type as this affects the firm's marginal cost. Poor countries do not buy in equilibrium if their willingness to pay is below $\gamma_L = 1/2$.[13] The reason is that the firm's marginal costs when selling to the rich are too high in relation to the poor countries' reservation price. This defines the lower threshold for γ_L in Assumption 1.

Solving the system of Equations (10) and (11) yields the following equilibrium prices and quantities in Table 1:[14]

		Prices		Quantities	
		p_H^{PD}	p_L^{PD}	d_H^{PD}	d_L^{PD}
$\kappa = 0$		$\frac{1}{2}$	$\frac{\gamma_L}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
$\kappa = 1$	$\gamma_L > \hat{\gamma}^{PD}$	$\frac{4\gamma_L+1}{4\gamma_L+2}$	$\frac{\gamma_L(2\gamma_L+3)}{4\gamma_L+2}$	$\frac{1}{4\gamma_L+2}$	$\frac{2\gamma_L-1}{2(2\gamma_L+1)}$

Table 1: Equilibrium under price discrimination for constant marginal costs ($\kappa = 0$) and increasing marginal costs ($\kappa = 1$) for the case that all countries buy positive quantities ($\gamma_L > \hat{\gamma}^{PD}$).

Lemma 1. *Under price discrimination all countries buy positive quantities if and only if* $\gamma_L > \hat{\gamma}^{PD}$*, where* $\hat{\gamma}^{PD}$ *equals* 0 *for constant and* 1/2 *for increasing marginal costs. Rich countries pay a higher price than poor countries.*

Proof. All proofs can be found in Appendix II. □

The finding that countries with a lower willingness to pay obtain a lower price than countries with a higher willingness to pay is a basic insight for third degree price discrimination as, for example, discussed by Armstrong (2006). The derivative of the price for poor countries in Table 1 with respect to γ_L is positive. The lower the willingness to pay of poor countries becomes, the lower their discriminating price for constant marginal costs. For increasing marginal costs the derivative of both prices in Table 1 with respect to γ_L is positive. In this case a lower willingness to pay of poor countries, lowers both discriminating prices due to a lower quantity demanded by poor countries. This results from the supplier being at a lower point on its marginal cost curve.

4.2 Uniform price (UP)

A share of poor countries $l \in (0, 1]$ and a share of rich countries $h \in (0, 1]$ are members of the buyer group. The buyer group procures jointly at a uniform price p_G. Each member country is free to choose a quantity at this price. Countries that did not join the buyer group (ROW or non-member countries) procure individually. We start with solving the

[13] See proof of Lemma 1.

[14] We calculate consumer surplus in Section 5 based on equilibrium prices and quantities in Table 1. The Appendix I comprises equilibrium total consumer surplus and welfare for the PD procurement rule.

equilibrium of the subgame starting in stage 2. In stage 2, non-member countries of type i face a price p_i while member countries face the uniform price p_G that the supplier sets for members of the buyer group.

This yields a total demand of

$$Q(p_L, p_H, p_G) = l \cdot q_{LG}(p_G) + h \cdot q_{HG}(p_G) + (1-l) \cdot d_L(p_L) + (1-h) \cdot d_H(p_H),$$

where $l \cdot q_{LG}(p_G) + h \cdot q_{HG}(p_G)$ is the aggregate demand of the buyer group.

In stage 1, the supplier sets different prices for the two country types and the buyer group to maximize its profits:

$$\max_{p_H, p_L, p_G} \pi = p_G \left[h \cdot q_{HG} + l \cdot q_{LG}\right] + (1-l)p_L d_L + (1-h)p_H d_H - C\left(Q\right), \tag{12}$$

with $C(Q) = \kappa \cdot Q^2$.
Differentiation yields the first order conditions

$$\frac{\partial \pi}{\partial p_H} = (1-h)\left[d_H(p_H) + p_H \frac{\partial d_H(p_H)}{\partial p_H} - \frac{\partial C(Q)}{\partial Q}\frac{\partial d_H(p_H)}{\partial p_H}\right] = 0, \tag{13}$$

$$\frac{\partial \pi}{\partial p_L} = (1-l)\left[d_L(p_L) + p_L \frac{\partial d_L(p_L)}{\partial p_L} - \frac{\partial C(Q)}{\partial Q}\frac{\partial d_L(p_L)}{\partial p_L}\right] = 0, \tag{14}$$

$$\begin{aligned}\frac{\partial \pi}{\partial p_G} = {} & h\left[q_{HG}(p_G) + p_G \frac{\partial q_{HG}(p_G)}{\partial p_G} - \frac{\partial C(Q)}{\partial Q}\frac{\partial q_{HG}(p_G)}{\partial p_G}\right] \\ & + l\left[q_{LG}(p_G) + p_G \frac{\partial q_{LG}(p_G)}{\partial p_G} - \frac{\partial C(Q)}{\partial Q}\frac{\partial q_{LG}(p_G)}{\partial p_G}\right] = 0.\end{aligned} \tag{15}$$

Observe that the first order conditions (13) and (14) for non-members are for a given total quantity Q the same as the first order conditions (10) and (11) under price discrimination. Observe further that the first order condition (15) for the group price p_G is a weighted average of the first order conditions for the non-members given $q_{iG} = d_i(p_G)$, which implies that the group price is between the non-member prices.

For constant marginal costs ($\kappa = 0$), the terms of Equations (13), (14) and (15) involving $\partial C(Q)/\partial Q$ vanish. As in the PD case, the optimal prices for non-member countries are independent of the demand of the other country type. Additionally, they are independent of the demand of the buyer group and the composition of the buyer group i.e., h and l, here.[15] The optimal uniform price for the group depends on the demand of rich and poor members and the shares of group member types, h and l, which (basically) weight the impact of the different demands on the uniform price. Poor member countries do not buy in equilibrium if their willingness to pay is below $\gamma_L = (h-l)/2h \geq 0$.[16] This results from the supplier charging a uniform price that is equal or higher than the poor countries' reservation price. In this case the group price equals the price for rich non-member countries.

[15] If we consider for example Equation (13) such that the last term is zero, dividing by the constant term $(1-h)$ does not change the outcome. In fact the foc is then the same as for the constant marginal costs PD case in Equation (10). The same holds for Equation (14).

[16] See proof of Lemma 2.

For increasing marginal costs ($\kappa = 1$), each price typically depends on the demand of all others due to the cost function first and secondly, on the composition of the buyer group. Here poor members do not buy in equilibrium if their willingness to pay is below $\gamma_L = \hat{\gamma}$, where $\left(\sqrt{5h^2+2hl+l^2}+h-l\right)/4h \leq \hat{\gamma} \leq 1/4(1+\sqrt{5})$ holds.[17] The lower bound results from the supplier charging a uniform price which exceeds the poor countries' reservation price, whereas the upper bound results from the supplier not serving poor members because it is more profitable. We abstract from the case in which poor non-members do not buy in equilibrium either, so that all poor countries buy nothing. This occurs if the willingness to pay of poor countries is below $\gamma_L = 1/2$, which Assumption 1 rules out for increasing marginal costs. Solving the system of Equations (13), (14) and (15) yields the equilibrium quantities and prices in Table 2.[18]

Prices

		p_H^{UP}	p_L^{UP}	p_G^{UP}
$\kappa = 0$	$\gamma_L > \hat{\gamma}_1^{UP}$	$\frac{1}{2}$	$\frac{\gamma_L}{2}$	$\frac{(h+l)\gamma_L}{2(h\gamma_L+l)}$
	$\gamma_L \leq \hat{\gamma}_1^{UP}$	$\frac{1}{2}$	$\frac{\gamma_L}{2}$	$\frac{1}{2}$
$\kappa = 1$	$\gamma_L > \hat{\gamma}_2^{UP}$	$\frac{4\gamma_L+1}{4\gamma_L+2}$	$\frac{\gamma_L(2\gamma_L+3)}{4\gamma_L+2}$	$\frac{\gamma_L(2(2h+l)\gamma_L+h+3l)}{2(2\gamma_L+1)(h\gamma_L+l)}$
	$\frac{1}{2} < \gamma_L \leq \hat{\gamma}_2^{UP}$	$\frac{(l-4)\gamma_L+l-1}{2(l-2\gamma_L-1)}$	$\frac{\gamma_L(2l-2\gamma_L-3)}{2(l-2\gamma_L-1)}$	$\frac{(l-4)\gamma_L+l-1}{2(l-2\gamma_L-1)}$

Quantities

		d_H^{UP}	d_L^{UP}	q_{HG}^{UP}	q_{LG}^{UP}
$\kappa = 0$	$\gamma_L > \hat{\gamma}_1^{UP}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{h\gamma_L+l(-\gamma_L)+2l}{2(h\gamma_L+l)}$	$\frac{2h\gamma_L-h+l}{2(h\gamma_L+l)}$
	$\gamma_L \leq \hat{\gamma}_1^{UP}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	0
$\kappa = 1$	$\gamma_L > \hat{\gamma}_2^{UP}$	$\frac{1}{4\gamma_L+2}$	$\frac{2\gamma_L-1}{4\gamma_L+2}$	$\frac{(h+l)\gamma_L-2l\gamma_L^2+2l}{2(2\gamma_L+1)(h\gamma_L+l)}$	$\frac{4h\gamma_L^2-2h\gamma_L-h+2l\gamma_L-l}{2(2\gamma_L+1)(h\gamma_L+l)}$
	$\frac{1}{2} < \gamma_L \leq \hat{\gamma}_2^{UP}$	$\frac{l\gamma_L-l+1}{-2l+4\gamma_L+2}$	$\frac{-(1-2\gamma_L)}{-2l+4\gamma_L+2}$	$\frac{l\gamma_L-l+1}{-2l+4\gamma_L+2}$	0

Table 2: Equilibrium under uniform pricing for constant marginal costs ($\kappa = 0$) and increasing marginal costs ($\kappa = 1$) for the cases that all countries buy positive quantities ($\gamma_L > \hat{\gamma}$) and that poor members do not buy ($\gamma_L \leq \hat{\gamma}$).

Lemma 2. *Under uniform pricing all countries buy positive quantities if and only if*

[17] See proof of Lemma 2.

[18] We calculate consumer surplus in Section 5 based on the equilibrium prices and quantities of Table 2. Appendix I contains the resulting aggregate consumer surplus and welfare for the UP procurement rule.

$\gamma_L > \hat{\gamma}_1^{UP} = (h-l)/2h \geq 0$ in the case of constant marginal costs. If $\gamma_L \leq \hat{\gamma}_1^{UP}$, poor member countries buy nothing. For increasing marginal costs, all countries buy positive quantities if and only if $\gamma_L > \hat{\gamma}_2^{UP}$ for $\left(\sqrt{5h^2+2hl+l^2}+h-l\right)/4h < \hat{\gamma}_2^{UP} < 1/4(1+\sqrt{5})$. For $\gamma_L \leq \hat{\gamma}_2^{UP}$, poor member countries are not served. Under uniform pricing rich non-member countries pay a higher price than poor non-member countries: $p_H^{UP} > p_L^{UP}$. The uniform price for the buyer group lies between these two prices $p_H^{UP} \geq p_G^{UP} > p_L^{UP}$.

As in the PD case, the supplier charges higher prices for countries with a higher willingness to pay for non-members (see Lemma 1). If poor member countries buy nothing, rich members face the same price as rich non-member countries because the aggregate demand of the buyer group equals the demand of rich members. If all members of the buyer group buy a positive quantity, the supplier sets a uniform price for this aggregate demand, which lies between the discriminating prices for non-member countries. Armstrong (2006) denotes this uniform price as a "kind of average price" of the discriminating prices. Therefore, rich members gain from the uniform price procurement rule, while poor members lose. These results hold independent of the cost function. For the comparative statics of this average price we take the derivative of the price for the buyer group if all buy in Table 2 with respect to the willingness to pay of poor members γ_L and the composition of the buyer group h and l. For both cost functions the derivative with respect to γ_L and h is positive, whereas the derivative with respect to l is negative. The more rich countries are members of the buyer group or the more similar the countries within the group are, the higher is the uniform price. The first results from a higher weight for the high willingness to pay demand of rich members compared to the demand of poor members for the aggregate demand of the buyer group. The second results from a higher reservation price and a less elastic demand of poor members and therefore of the aggregate demand. A higher share of poor members lowers the uniform price due to a higher weight for the low willingness to pay demand of poor members. Thus, the more heterogeneous the group (as long as poor members buy) and the higher the share of poor members, the higher the gain for rich members under uniform pricing.[19]

4.3 Uniform quantity (UQ)

A share of poor countries $l \in (0,1]$ and a share of rich countries $h \in (0,1]$ are members of the buyer group. The buyer group procures jointly at a uniform price p_G. Member countries buy the quantity that the country with the lowest WTP would buy at this uniform price (i.e., $q_{LG} = q_{HG} = d_L(p_G)$) denoted as q_G according to the mechanism described in Section 3. Non-members procure individually. We start with solving the equilibrium of the subgame starting in stage 2. In stage 2, non-member countries of type i face a price p_i while member countries face the uniform price p_G that the supplier sets for buyer group members. This yields a total demand of

$$Q(p_L, p_H, p_G) = (l+h) \cdot q_G(p_G) + (1-l) \cdot d_L(p_L) + (1-h) \cdot d_H(p_H),$$

[19]Note that rich members (and all other countries that still buy) also benefit, if (more) poor members buy a zero quantity under increasing marginal costs. This results from the supplier being on a lower point on its marginal cost curve due to a lower total quantity demanded.

where $(l+h)\cdot q_G(p_G)$ is the aggregate demand of the buyer group.

In stage 1, the supplier sets different prices for the two country types and the buyer group to maximize its profits:

$$\max_{p_H,p_L,p_G} \pi = (l+h)\cdot p_G \cdot q_G(p_G) + (1-l)\cdot p_L \cdot d_L(p_L) + (1-h)\cdot p_H \cdot d_H(p_H) - C\left(Q\right) \quad (16)$$

with $C(Q) = \kappa \cdot Q^2$.
Differentiation yields the first order condition

$$\frac{\partial \pi}{\partial p_H} = (1-h)\left[d_H(p_H) + p_H \frac{\partial d_H(p_H)}{\partial p_H} - \frac{\partial C(Q)}{\partial Q}\frac{\partial d_H(p_H)}{\partial p_H}\right] = 0, \quad (17)$$

$$\frac{\partial \pi}{\partial p_L} = (1-l)\left[d_L(p_L) + p_L \frac{\partial d_L(p_L)}{\partial p_L} - \frac{\partial C(Q)}{\partial Q}\frac{\partial d_L(p_L)}{\partial p_L}\right] = 0, \quad (18)$$

$$\frac{\partial \pi}{\partial p_G} = (h+l)\cdot\left[q_G(p_G) + p_G \frac{\partial q_G(p_G)}{\partial p_G} - \frac{\partial C(Q)}{\partial Q}\frac{\partial q_G(p_G)}{\partial p_G}\right] = 0. \quad (19)$$

Observe that the terms in the brackets of the first order conditions (18) and (19) for p_L and p_G are identical for $p_L = p_G$ given $d_L(p_G) = q_G$. This implies that the optimal price for poor non-members equals the price for the buyer group. The first order conditions (18) and (17) for the prices of non-members are, for a given total quantity Q, equivalent to the first order conditions for p_L and p_H in the previous cases.

For constant marginal costs ($\kappa = 0$), the last terms of Equations (17), (18) and (19) vanish. As in the UP case, the optimal prices for non-member countries are independent of the demand of the other country type and the demand and composition of the buyer group. But here the optimal price for the buyer group is also independent of the demand of non-members and the group composition. The buyer group obtains the same price as poor non-member countries.[20] The constraint that demand has to be non-negative does not bind.

For increasing marginal costs ($\kappa = 1$), each price typically depends on the demand of all others through the cost function. In general, the composition of the buyer group can also influence demand. Here poor non-members and the buyer group do not buy in equilibrium if their willingness to pay is below $\gamma_L = (1-h)/(2-h)$. This results from solving the equilibrium quantity at $q_G = d_L = 0$. However, it holds that $(1-h)/(2-h) < 1/2$ and therefore, we only consider the case at which all types buy positive quantities under UQ due to Assumption 1. Solving the system of Equations (17), (18) and (19) yields the equilibrium quantities and prices in Table 3.[21]

[20] If we consider Equation (18) and (19) such that the last term is zero, dividing by the constant term $(h+l)$ and $(1-l)$ does not change the outcomes. From the mechanism we obtain $q_G = d_L(p_G)$ and the focs yield the same optimal price.

[21] We calculate consumer surplus in Section 5 based on the equilibrium prices and quantities of Table 3. Appendix I contains the resulting aggregate consumer surplus and welfare for the UQ procurement rule.

		Prices		
		p_H^{UQ}	p_L^{UQ}	p_G^{UQ}
$\kappa = 0$		$\frac{1}{2}$	$\frac{\gamma_L}{2}$	$\frac{\gamma_L}{2}$
$\kappa = 1$	$\gamma_L > \frac{1}{2}$	$\frac{(h-4)\gamma_L - h - 1}{2(h-2)\gamma_L - 2(h+1)}$	$\frac{\gamma_L((h-2)\gamma_L - h - 3)}{2(h-2)\gamma_L - 2(h+1)}$	$\frac{\gamma_L((h-2)\gamma_L - h - 3)}{2(h-2)\gamma_L - 2(h+1)}$
		Quantities		
		d_H^{UQ}	d_L^{UQ}	q_G^{UQ}
$\kappa = 0$		$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
$\kappa = 1$	$\gamma_L > \frac{1}{2}$	$\frac{h\gamma_L - h - 1}{2(h\gamma_L - h - 2\gamma_L - 1)}$	$\frac{(h-2)\gamma_L - h + 1}{2(h-2)\gamma_L - 2(h+1)}$	$\frac{(h-2)\gamma_L - h + 1}{2(h-2)\gamma_L - 2(h+1)}$

Table 3: Equilibrium under uniform quantity for constant marginal costs ($\kappa = 0$) and increasing marginal costs ($\kappa = 1$) for the case that all countries buy positive quantities ($\gamma_L > 1/2$).

Lemma 3. *Under uniform quantity all countries buy positive quantities if $\gamma_L > 0$ $(1/2)$ in the case of constant (increasing) marginal costs. The buyer group pays the same price as poor non-members countries which is lower than the price for rich non-members.*

The buyer group countries obtain the same price and quantities as poor non-member countries. This results from the commitment of the buyer group members to buy equal quantities in the amount of the quantity that the poor members (lowest WTP members) would buy at a uniform price. Therefore, the demand for each buyer group member is equal to the demand of poor non-members. While poor countries have the same outcome independent of the membership, rich non-members have to pay a higher price than rich members. This holds independent of the costs function. Due to constant and equal demanded quantities by all country types resulting from the linear demand function used, rich members can procure their optimal quantity for constant marginal costs. In this case the equilibrium outcomes for rich non-members and poor non-members (which are the same as for the buyer group here) and therefore, the comparative statics under uniform quantity procurement are unchanged to the price discrimination case for constant marginal costs (see Subsection 4.1). For increasing marginal costs rich members still pay a lower price than rich-non-members but are restricted in quantity that they can procure. Thus, the uniform quantity procurement results in a trade-off for rich members between a low price and an over-commitment to low quantities for increasing marginal costs. The derivative of the price for the buyer group in Table 3 with respect to γ_L is positive. The lower the willingness to pay of poor countries becomes, the lower the price for poor non-members and buyer group members but also the lower the quantity procured for increasing marginal costs. Independent of the costs function the share of poor members has no effect on outcomes, since it doesn't make a difference if they are group

members or not. However, the derivative of the prices in Table 3 with respect to h is negative for increasing marginal costs. The more rich countries join the buyer group, the lower the prices for all country types. This results from more countries that are restricted in quantity and the supplier being on a lower points on its marginal costs curve due to a lower quantity demanded. We denote this as monopsony effect.

4.4 Profits

We plug the equilibrium quantities and prices derived in Table 1, 2 and 3 in Equations (9), (12) and (16) to derive the profits of the supplier.

		Profits PD (π^{PD})
$\kappa = 0$		$\frac{1}{4}(\gamma_L + 1)$
$\kappa = 1$	$\gamma_L > \hat{\gamma}^{PD}$	$\frac{2\gamma_L^2 - \gamma_L + 1}{4(2\gamma_L + 1)}$
		Profits UP (π^{UP})
$\kappa = 0$	$\gamma_L > \hat{\gamma}_1^{UP}$	$\frac{-hl\gamma_L^2 + 2hl\gamma_L - hl + h\gamma_L^2 + h\gamma_L + l\gamma_L + l}{4(h\gamma_L + l)}$
	$\gamma_L \leq \hat{\gamma}_1^{UP}$	$\frac{1}{4}(-l\gamma_L + \gamma_L + 1)$
$\kappa = 1$	$\gamma_L > \hat{\gamma}_2^{UP}$	$\frac{\gamma_L(\gamma_L(-2h(l-1)\gamma_L + h(3l-1) + 2l) + h - l) - hl + l}{4(2\gamma_L + 1)(h\gamma_L + l)}$
	$1/2 < \gamma_L \leq \hat{\gamma}_2^{UP}$	$\frac{2l\gamma_L^2 - 2l\gamma_L + l - 2\gamma_L^2 + \gamma_L - 1}{4(l - 2\gamma_L - 1)}$
		Profits UQ (π^{UQ})
$\kappa = 0$		$\frac{1}{4}((h+1)\gamma_L - h + 1)$
$\kappa = 1$	$\gamma_L > 1/2$	$\frac{\gamma_L\left(-2h^2 + (h-2)(h+1)\gamma_L + h + 1\right) + h^2 - 1}{4(h-2)\gamma_L - 4(h+1)}$

Table 4: Equilibrium profits for constant marginal costs ($\kappa = 0$) and increasing marginal costs ($\kappa = 1$) for the case that all countries buy positive quantities ($\gamma_L > \hat{\gamma}$) and that poor members do not buy ($\gamma_L \leq \hat{\gamma}$).

We compare the profits in Tables 4 for constant and increasing marginal costs in the following.

Proposition 1. *The supplier obtains the highest profits under price discrimination, the second highest under uniform price procurement and the lowest under uniform quantity procurement.The intuition for the result is that the monopolist is restricted by the joint procurement mechanisms. Uniform pricing limits the ability to price discriminate and uniform quantity on top limits the quantity sold. Each limitation restricts the supplier and strictly lowers its profitability.*

5 Choice of procurement rule

In this section we study the optimal procurement choice. First we evaluate, which procurement rule is Pareto optimal for the members of the buyer group. If compensation payments are not feasible, a Pareto improvement might be necessary for a buyer group to form. For example if participation is voluntary, countries that are worse off have no incentive to join. Secondly, we discuss which procurement rule maximizes the joint surplus of all members of the buyer group. This is particularly plausible if compensation payments between member countries are feasible. If transfers are possible, all members can be made better off whenever the total surplus of buyers in the group increases.

Pareto optimality of procurement rules. Comparing the outcomes for members countries under uniform pricing to their outcomes under price discrimination yields

Proposition 2. *Uniform pricing is not a Pareto improvement to price discrimination. Poor member countries are always worse off under uniform pricing whereas rich member countries are weakly better off; they are strictly better off in all cases except for the case of constant marginal costs if γ_L is sufficiently low, such that poor members do not buy under uniform pricing (i.e., $\gamma_L \leq \hat{\gamma}_1^{UP}$).*

Under uniform pricing, both country types in the buyer group commit to buy at a single price. This results in a price for the buyer group that is between the prices for poor and rich countries under price discrimination. Hence, poor countries are worse off, whereas rich countries typically benefit. The only case in which rich countries are not strictly better off is the case where uniform pricing results in zero quantities for poor countries under constant marginal costs. In this case rich countries face the same price with price discrimination as with the buyer group and uniform pricing because the supplier does not account for the lower willingness to pay of poor members under uniform pricing.

With increasing marginal costs, rich countries strictly benefit from uniform pricing. If poor members do not buy at the uniform price, their demand reduction has a positive externality on rich countries because the supplier is consequently at a lower point of its increasing marginal cost curve.

Overall, uniform pricing cannot be a Pareto improvement compared to price discrimination as poor countries are always worse off. This holds independently of the cost function and resembles the results in the literature on price discrimination. For instance, Armstrong (2006) documents this for the case of two heterogeneous buyer types.

Comparing the outcomes for member countries under uniform quantity procurement and price discrimination yields

Proposition 3. *For constant marginal costs, uniform quantity procurement is Pareto superior to price discrimination for group members. For increasing marginal costs and if γ_L is sufficiently high, uniform quantity procurement is Pareto superior to price discrimination for group members. In particular, both types of member countries are strictly better off with uniform quantity procurement. If γ_L is sufficiently small and $h < 4/7$, uniform quantity procurement is worse for rich member countries than price discrimination.*

For constant marginal costs, poor members obtain the same price under uniform quantity procurement as under price discrimination. For increasing marginal costs, poor members obtain a lower uniform price under uniform quantity procurement than under price discrimination. This results from the supplier being at a lower point of its marginal cost curve due to the reduced quantity that rich members get under uniform quantity procurement. We defined that as the monopsony effect in Subsection (4.3). In any case that we consider, poor members obtain a surplus under uniform quantity procurement that is at least equal to the surplus obtained under price discrimination.
Rich members benefit in the case of constant marginal costs from the low uniform price under uniform quantity procurement compared to their discriminating price. Additionally, rich members can procure their optimal quantity, which is equal to the quantity demanded by poor members here. Therefore, rich members are strictly better off with uniform quantity procurement compared to price discrimination and the procurement rule is Pareto optimal for constant marginal costs.

For increasing marginal costs, rich members face a trade off under uniform quantity procurement. They benefit from a low uniform price due to the procurement rule and the monopsony effect. But in this case the procurement rule restricts rich members to buy a quantity that is less than optimal for them. Rich members obtain a higher surplus under the uniform quantity procurement compared to price discrimination if the willingness to pay of the buyer group members is not too heterogeneous. The more similar the member countries are (the higher is γ_L), the less restrictive is the quantity restriction for rich members. How much this degree of heterogeneity can vary depends on the share h of rich countries that are group members. A lower share h leads to a weaker monopsony effect and the group members have to be even more similar regarding their willingness to pay to make rich members better off compared to price discrimination. The value $\gamma_L = 0.81$ is sufficiently high to ensure that rich members are better off under the uniform quantity procurement for any group composition. The procurement rule is then also Pareto optimal for increasing marginal costs.

Aggregate consumer surplus of the buyer group. We compare the aggregate consumer surplus for the buyer group under uniform pricing to their outcomes under price discrimination.

Proposition 4. *For constant marginal costs the aggregate consumer surplus of the buyer group under uniform pricing is larger than under price discrimination if $\gamma_L > \hat{\gamma}_1^{UP}$ so that also poor members buy positive quantities under uniform pricing. The opposite holds for $\gamma_L \leq \hat{\gamma}_1^{UP}$.*
Suppose that marginal costs increase. For $\gamma_L > \hat{\gamma}_2^{UP}$ the aggregate surplus of the buyer group with uniform pricing is always larger than for price discrimination. For $\gamma_L \leq \hat{\gamma}_2^{UP}$ there exists a critical value $\hat{h}$, such that for $h > \hat{h}$ the uniform pricing procurement rule yields a higher aggregate surplus than price discrimination and for $h \leq \hat{h}$ the opposite holds.

The aggregate surplus of the group is higher for uniform pricing than for price discrimination if all countries buy. Even though poor member always suffer from uniform pricing relative to price discrimination, rich members benefit from the uniform price. This

outweighs the lower surplus of poor members and the joint surplus is higher for the group with uniform pricing. If compensation payments from rich to poor members are feasible, the uniform pricing procurement is favorable for the buyer group compared to price discrimination if the degree of heterogeneity is sufficiently low, such that all countries buy under uniform pricing. If poor members buy nothing under uniform pricing, price discrimination yields a higher surplus for the group than uniform pricing for constant marginal costs. This also holds for increasing marginal costs if the share of rich members is sufficiently low. Then the (aggregate) surplus of rich members is not high enough to outweigh the zero surplus of poor members under uniform pricing.

Comparing the aggregate consumer surplus for the buyer group under uniform pricing to their outcomes under uniform quantity yields

Proposition 5. *For constant marginal costs the comparison of procurement according to the aggregate consumer surplus of the buyer group is non-monotonic in γ_L. For $\gamma_L \leq \hat{\gamma}_1^{UP}$poor members do not buy and uniform quantity procurement yields a higher surplus. If poor countries buy under uniform pricing, that is $\gamma_L > \hat{\gamma}_1^{UP}$, the aggregate surplus of the buyer group is higher for uniform price procurement compared to uniform quantity if $\gamma_L \leq l/(2h+3l)$. For $\gamma_L > l/(2h+3l)$ uniform quantity procurement yields a higher surplus. For increasing marginal costs, uniform quantity procurement can yield a higher aggregate surplus for the buyer group depending on its composition h and l and the degree of heterogeneity γ_L.*

Uniform quantity procurement can yield a higher aggregate surplus for the buyer group than uniform pricing by restricting the quantity and thus lowering the price. For constant marginal costs uniform quantities strictly increase the aggregate surplus over uniform pricing. For increasing marginal costs the quantity restriction of uniform quantity purchasing can be excessive. Then uniform quantity may be worse than uniform pricing. This can be the case if countries are too heterogeneous in the sense that γ_L is too low. Intuitively the poorer the poor countries are, the more restricted the purchasing quantity under uniform quantity is. Note that there is an optimal quantity restriction from the point of view of the buyer group that is inversely u-shaped in γ_L , meaning that for large heterogeneity between countries: quantities are too low, while for very similar countries in the group: quantities are not restricted enough to realize the optimal monopsony effect.

To determine when the buyer group chooses which joint procurement rule if transfers are possible, we provide comparative statics for the country-specific surpluses in h and l to discuss the effects for the aggregate consumer surplus for constant and increasing marginal for UP and UQ. [22]

Proposition 6. *First, we consider the uniform price procurement. If both member types buy, $\gamma_L > \hat{\gamma}^{UP}$, the surpluses of all members decrease in the share of rich members, h, and increase in the share of poor members, l. If poor countries do not buy, $\gamma_L \leq \hat{\gamma}^{UP}$, the surplus of rich members is independent of the share of rich members, h, and for constant marginal costs the surplus of rich members is also independent of the share of*

[22]We do not consider the comparative statics for the country-specific surpluses of the member countries in γ_L because the parameter changes the demand of poor countries and therefore, the interpretation for poor countries is not meaningful.

poor members, l, whereas it is increasing in l for increasing marginal costs.
Secondly we consider the uniform quantity procurement. The surplus of all member types is independent of l. For constant marginal costs both surpluses are independent of h while for increasing marginal costs they increase in h.

For constant marginal costs the uniform quantity procurement increases the aggregate surplus compared to uniform pricing. However, for increasing marginal costs the comparison between uniform quantity and uniform pricing depends on the group composition. With uniform pricing the price decreases the more poor countries are in the group while for uniform quantities the prices decreases in the number of rich countries that limit their quantities by being in the group. Hence, uniform pricing tends to be attractive for groups with a large share of poor countries while uniform quantity tends to be preferred if a large share of rich countries is in the buyer group.

In summary, for the buyer group uniform pricing is not a Pareto improvement to price discrimination and thus will only be consented by poor and rich group members if compensatory transfers from rich to poor members are feasible. Uniform quantity procurement can be a Pareto improvement without transfers. For example, if the willingness to pay within group members is similar enough, the procurement rule is Pareto optimal rule for the buyer group among the cases we consider.

In terms of aggregate surplus of the buyer group, uniform quantity procurement can be better or worse than uniform pricing. This depends on the composition of the group and the heterogeneity of the members' willingness to pay. A buyer group with a high share of rich members is better off with uniform quantity procurement due to the strong monopsony effect. The same holds if the group members are similar regarding their willingness to pay due to the less pronounced quantity restriction. For a buyer group with a high share of poor and a low share of rich members where the members are relatively heterogeneous, however, the uniform pricing procurement yields a higher aggregate surplus for the group.

6 Buyer group stability

In certain settings it might be the case that the buyer group is exogenously determined. A case in point is a joint procurement by the European Union for its member states, where the EU as a group existed before the decision to act as a buyer group. However, even in this setting, it might be the case that member states can opt out of the joint procurement, such that even in that setting the buyer group might form endogenously in view of the procurement at stake. In principle, one could also think about a situation with a different timing, where a buyer group forms after a procurement rule is announced. For instance, a buyer group might first announce the strategy and countries can join afterwards. In this section we analyze how stable the buyer group is at a certain size, i.e. do member countries have an incentive to leave the group? Therefore, we compare the surpluses of members and non-members of the same type. This is possible as an individual country has mass zero and thus does not influence the aggregate outcome.

First we consider the case without transfers within in the group. In this case we define the buyer group as stable if the individual surplus of each country in the group is weakly

larger than the surplus of a country of the same type outside the group given the group still exists: for UP it is $cs_{iG}^{UP} \geq cs_i^{UP}$ and for UQ $cs_{iG}^{UQ} \geq cs_i^{UQ}$for all $i \in H, L$.

In case transfers are possible the stability may be achieved differently. The conditions become $cs_{iG}^{UP} + t_i \geq cs_i^{UP}$ for UP and for UQ $cs_{iG}^{UQ} + t_i \geq cs_i^{UQ}$, where we assume that $ht_H + lt_L = 0$ for budget balance.

Comparative statics. We derive the effects for non-members under uniform quantity procurement in the following.[23]

Lemma 4. *For constant marginal costs the group composition has no effect on the surplus of non-member countries under uniform quantity procurement. This also holds for the share of poor members for increasing marginal costs. However, a higher share of rich members increases the surpluses of non-member countries for increasing marginal costs.*

The effects of the group composition for non-members are analog to the ones for members discussed in Proposition 6. Non-members obtain a lower (discriminating) price under the uniform quantity procurement rule if the share of rich members increase. We define that as the free-riding effect.

Without transfers. Comparing the outcomes of member countries to non-member countries under the uniform price procurement rule yields

Proposition 7. *Uniform pricing is not stable without transfers. Poor member countries are worse off with uniform pricing compared to poor non-member countries in all cases. Rich members are as well off with uniform pricing as rich non-members if poor members do not buy under uniform pricing*, i.e. $\gamma_L \leq \hat{\gamma_1}^{UP}$ *for constant marginal costs and* $\gamma_L \leq \hat{\gamma_2}^{UP}$ *for increasing marginal costs. Rich member countries are better off with uniform pricing than rich non-member countries if all countries buy, that is if* $\gamma_L > \hat{\gamma_1}^{UP}$ *for constant marginal costs and* $\gamma_L > \hat{\gamma_2}^{UP}$ *for increasing marginal costs.*

Prices for non-member countries under the uniform pricing procurement rule are typically the same as for price discrimination. There are no externalities from the demand of the buyer group if the member's total demand is unchanged, such that the supplier is at the same point of its marginal cost curve. In this case, comparing the surpluses for any country type of non-members to members under uniform pricing is the same as comparing the surpluses for countries procuring under price discrimination to procuring as a members under uniform pricing (Lemma 2). The only exception from this analogy is the comparison for increasing marginal costs for rich members and non-members if poor members buy nothing. In this case the total quantity procured under uniform pricing is different to the total quantity procured under price discrimination. With uniform pricing, rich countries obtain the same surplus independent of the membership as the supplier sets the buyer group price only in view of the demand of rich countries if poor members demand nothing.

Overall, this implies that rich countries have an incentive to stay within the buyer group with uniform pricing while poor countries are better off leaving the group. Hence,

[23]We again do not consider the comparative statics in γ_L as discussed in Proposition 6.

the establishment of such a buyer group might require transfers from rich to poor member countries. Without compensation the buyer group under uniform pricing is not stable.

Comparing the outcomes of member countries to non-member countries under the uniform quantity procurement rule yields

Proposition 8. *Uniform quantity procurement is stable for constant marginal costs. For increasing marginal costs stability depends on the degree of heterogeneity and the share of rich members. Under uniform quantity procurement poor members are as well off as poor non-members in any case. Rich members are better off than rich non-members for constant marginal costs. This also holds for increasing marginal costs if the share of rich members h or γ_L is sufficiently large.*

Poor countries have no incentive to leave the buyer group under uniform quantity procurement. They obtain the same prices and therefore, surpluses independent of the membership. For constant marginal costs rich members are always better off than rich non-members under uniform quantity procurement. This results from the lower price that rich members can obtain under the joint procurement, while procuring the same quantity as rich non-members. For increasing marginal costs it depends on the share of rich countries or the degree of heterogeneity if rich members have an incentive to opt out. If the buyer group consists of a high share of rich members, many countries are restricted in quantity and the monopsony effect is large, which lowers the uniform price. If the degree of heterogeneity is low (i.e., γ_L high), the less restrictive is the quantity restriction for rich members. In both cases rich members are better off staying within the buyer group. Only if group members are rather heterogeneous and not enough rich countries join the buyer group, rich members obtain a higher surplus when leaving the buyer group. Then the buyer group would not be stable. In summary, the buyer group would not be stable under uniform price procurement without transfers. Poor members have always an incentive to leave the group. Under uniform quantity procurement the buyer group is stable except for the case when the group composition and the degree of heterogeneity are unfavorable for rich members (i.e., h and γ_L low).

With transfers. Let us now consider the case with transfers between the group members. Suppose that member countries stay in the group if it is unilaterally profitable with the transfer:

$$cs_{LG} + t_L \geq cs_L, \tag{20}$$

$$cs_{HG} + t_H \geq cs_H. \tag{21}$$

We assume that transfers have to be budget balanced:

$$l \cdot t_L + h \cdot t_H = 0. \tag{22}$$

Combing the stability conditions and the budget constraint (22) yields the necessary condition for stability with transfers that group members benefit on average from being

in the group:

$$\frac{h \cdot cs_{HG} + l \cdot cs_{LG}}{h+l} > \frac{h \cdot cs_H + l \cdot cs_L}{l+h}. \tag{23}$$

For the case of uniform price procurement, stability requires sufficient transfers from rich to poor members. It turns out that this is possible for the case where poor group members buy positive quantities in equilibrium.

Recall that in the case of uniform quantity procurement, poor member countries obtain the same surplus as poor non-member countries: $cs_{LG} = cs_L$. The budget restriction (22) implies $t_L \geq 0$. It is thus not possible to subsidize rich group members although their membership exerts a positive externality on poor group members (as well as on outsiders).

We summarize in

Proposition 9. *Suppose that transfers between group members are possible. With uniform price procurement, stability is achievable with transfers to poor members, but only in the case where poor group members buy positive quantities. With uniform quantity procurement, transfers do not increase stability and the outcome is as in Proposition 8.*

7 EU's COVID-19 vaccine procurement

In this section, we relate our model framework to the case of the EU's joint vaccine procurement in the COVID-19 pandemic already mentioned in the introduction.

In the influenza (H1N1) pandemic in 2009 European countries relied on self-procurement of vaccines.[24] Due to unequal outcomes in terms of vaccine access as well as partly unfavorable purchase conditions (prices, liability conditions, etc.) among the countries having different degrees of purchasing power, most countries were interested in a joint procurement to overcome these weaknesses. In 2014 the EU implemented a voluntary scheme to centrally procure, among others, vaccines for European health threats, the Joint Procurement Agreement (signed by 37 European nations).[25] The "EU Strategy for COVID-19 vaccines" entailed this procurement method to pool resources, to join negotiation power, reduce bargaining and eliminate competition between member states to secure vaccines.[26] The aim was to provide equitable access to an effective and safe vaccine among participants at affordable prices as quickly as possible. With advanced purchase agreements (APAs) as the main instruments the EU concluded contracts with pharmaceutical companies that were assessed as leading in COVID-19 vaccine research, about inter alia quantities, advanced payments - for risk-sharing and to overcome capacity constraints[27] - and uniform unit prices for its participating members states. A population-based distribution key determined the allocation between members. Once EU's contract bargaining was in progress

[24] See Stern, E. K., Young, S. "Assessment Report on EU-wide Pandemic Vaccine Strategies", European Commission, 25. August 2010, last accessed January 2022.

[25] See European Commission "Commission Decision of 10.4.2014 on approval of the Joint Procurement Agreement to procure medical countermeasures pursuant to Decision 1082/2013/EU", C(2014) 2258 final, 10. April 2014, last accessed January 2022.

[26] European Commission, "Communication from the Commission to the European Parliament, the European Council, the Council and the European Investment Bank. EU Strategy for COVID-19 vaccines", COM/2020/245 final, 17. June 2020, last accessed January 2022.

[27] Characteristics of vaccine supply are factors such as a time and capital (high fixed costs) intensive development involving high risks and low profitability, frequent occurrence of underinvestment's and a concentrated market structure (Sloan (2012), Douglas and Samant (2018)and Wouters *et al.* (2021)).

other negotiations should not be undertaken at the same time. At first all 27 member states of the EU participated. The member states differed in population size and GDP as well as in preferences for vaccine types (regarding e.g., vector or mRNA, their price categories, handling).[28] Summarizing the main outcomes of the procurement the EU secured almost all vaccines at lower prices than self-procuring countries as the United States of America (US).[29] But the EU ordered less vaccine quantities in relation to its population and lagged behind in negotiations, concluding contracts and vaccination rates during the first month of procurement and vaccine availability compared to the US.[30] The vaccination rates also varied among member states and not all of the members relied solely on the joint procurement but procured on their own additionally as Germany or Hungary.[31] Several economists critically analyzed the European strategy. They emphasized the low at-risk investments of the EU (through public funding in advance) to overcome the existing capacity constraints of COVID-19 vaccine production. Moreover, they pointed out the failure to provide sufficient incentives for firms to invest and quickly deliver vaccines to the EU due to low prices.[32] Despite the shortcomings, Dewatripont (2022) assessed that the EU "did reasonably well in procuring vaccines" during the pandemic. We conclude from this case example that it is not overall clear if the joint procurement of the EU can be considered as the most efficient method here but reveals certain advantages and disadvantages.

We relate this case example to our UQ procurement rule with increasing marginal cost. As in the case of the EU we consider a buyer group that procures for heterogeneous countries. We consider a mass of poor countries such as the European member states Romania or Bulgaria and rich countries as Germany or France, where rich countries have a higher WTP for the good than poor countries. For simplification we abstract from the public good character of vaccines and thus consumption externalities. As in the case example the buyer group can procure at a low price and specifies a predefined allocation

[28]For instance, Germany: 83.2 million citizens, GDP of $ 4.47 trillion (purchasing power parity, 2020) or Malta: 0.5 million citizens, GDP of $ 22.4 billion (purchasing power parity, 2020). Population data based on Eurostat "Key Figures on Europe", last accessed 20.06.2021 and GDP data according to Worldbank "GDP, PPP (current international $) - European Union",last accessed 20.06.2021. Information about preferences see Deutsch, Wheaton "How Europe fell behind on vaccines. The EU secured some of the lowest prices in the world. At what cost?", Politico, 27.01.2021, last accessed December 2021 and Grill, M., Mascolo, G. "EU-Impfstoffbestellungen: Warum die Verhandlungen so lange stockten", tagesschau, 05.02.2021, last accessed December 2021.

[29]E.g., EU paid $14.76 per unit for the mRNA vaccine of BioNTech/Pfizer, $18.00 per unit for the mRNA vaccine of Moderna and $2.19 per unit for the vector vaccine of Oxford/AstraZeneca, the US $19.50, $15.00 and $4.00 respectively according to Bernstein Research's report "Europe is paying less than U.S. for many coronavirus vaccines",The Washington Post, 18.12.2020, last accessed December 2021.

[30]Data on vaccination rates are from Our World in Data "Statistics and Research Coronavirus (COVID-19) Vaccinations", latest accessed 02.01.2021. For procurement contracts of EU and US see Duke Global Health Innovation Center "Launch and Scale Speedometer. Timeline of Covid-19 Vaccine Purchase Deals", latest accessed 02.01.2021.

[31]See Deutsch, Wheaton "How Europe fell behind on vaccines. The EU secured some of the lowest prices in the world. At what cost?", Politico, 27.01.2021, last accessed December 2021 and Grill, M., Mascolo, G. "EU-Impfstoffbestellungen: Warum die Verhandlungen so lange stockten", tagesschau, 05.02.2021, last accessed December 2021.

[32]See Höland, C. "Wirtschaftsforscher Bachmann über Impfstoffbeschaffung: ‚Nicht genug und nicht früh genug'", Redaktionsnetzwerk Deutschland, 02.02.2021, last accessed 07. July 2021 and Dewatripont (2022)

of quantities for its member countries.[33] We interpret the increasing marginal costs of the supplier as a form of capacity constraint. Additionally, we choose a monopolistic production representing the concentrated supply structure as it was observed for COVID-19 vaccine production. Non-member countries - as for example the US - represent other competitors on the demand side or simply the rest of the world and model the intense global competition on the demand side for the vaccine. Considering the above stated aims of the EU, it seems reasonable for us that the institution has an incentive to maximize the aggregate consumer surplus of its members under a fair allocation of goods. Our model implies that the buyer group, respectively the EU, obtains the highest possible aggregate consumer surplus and the most equitable access with its joint procurement strategy (i.e., UQ in our model) among the here considered alternatives if the member countries are not too heterogeneous. This is in accordance with the outcome of the paper by Marvel and Yang (2008) and confirms the statement of the EU in the introduction claiming that this procurement form is most efficient. If members states are too heterogeneous, our model suggest that this form can still be most effect in terms of the aggregate consumer surplus if a high share of rich countries join the buyer group. We also find that rich non-member countries such as the US can benefit from such a joint procurement form of other countries. Even if non-members have to pay a higher price than rich members, they gain from the quantity restriction of rich members for a capacity constraint supply. An effect that could be related to the case example again. The US as a self-procuring country was not only procuring faster but also procured larger vaccine quantities and could be therefore considered as more successful in the COVID-19 vaccine procurement than the EU. However, looking on the aggregate surplus of the buyer group only is not sufficient if not all members gain from the procurement rule and transfers between members are not feasible. We claim that the member countries have the priority of maximizing their own consumer surplus rather than to focus on solidarity in terms of aggregate consumer surplus or quantities and surplus of the other participants. That implies that rich members only prefer this fair allocation joint procurement (obtains its highest achievable country-specific surplus with this rule) if the other member countries are not too poor (here in terms of WTP) or if enough rich countries joint the buyer group. If this is not the case and the buyer group consists of a large share of poor members, we find that a uniform price procurement without a quantity restriction is favorable for rich members. This is never the case for poor members in our model. But poor member countries gain from the uniform quantity joint procurement form. This is in line with the results of the model of Ahuja *et al.* (2021), where lower income countries i.e., weaker participants, are the major beneficiaries of such strategies.

8 Conclusion

We compare market outcomes for self- and joint procurements of heterogeneous countries. Joint procurement can either take the form of a uniform pricing without or with a quantity restriction (i.e., uniform price and uniform quantity procurement) for the buyer group,

[33]For simplicity we assume an equal distribution of quantities for an equal population size here even if that does not exactly hold for the member states of the EU.

whereas the supplier sets a discriminating price for the country types in self-procurement (i.e., price discrimination). Thereby, we focus on the effects for the member countries of the buyer group in terms of the change in country-specific and aggregate consumer surplus. For this, we employ a model where fractions of the countries with low or high demand (labeled *poor* and *rich*) form a buyer group. For a given group composition, the member countries procure a good under different procurement rules and production technologies (i.e., constant or increasing marginal cost). Thereby they compete with a mass of other rich and poor countries that are not in a buyer group and rely on self-procurement.

Considering the country-specific surpluses of the member countries, we show that a uniform price procurement is not a Pareto improvement to price discrimination. Whereas rich members gain from the uniform price as it is lower than the price rich countries get with self-procurement, poor members lose. Uniform quantity procurement, instead, can be a Pareto improvement to price discrimination. This holds in any case for constant marginal costs and also for increasing marginal costs if the member countries are not too heterogeneous. In the latter case, rich members gain from the low uniform price and their commitment to buy the same quantity as the poor member countries, provided that the poor countries are similar enough, so that the restriction is not too harsh. The demand restriction of rich members results in a monopsony effect. For increasing marginal costs, poor members can benefit from the reduced uniform price, which arises due to the lower marginal production costs if rich members are restricted their demand.

Furthermore, we find that rich non-members can free-ride on the quantity reduction of rich members. This can render uniform quantity procurement unattractive for the buyer group but is less of a concern the more rich countries are part of the group as this reduces the collective action problem.

Overall, uniform price and quantity procurement can be adopted by the buyer group without transfers between members, whereas pure uniform price procurement can not. Uniform price procurement can yet be desirable for all members if transfers from rich to poor members are feasible. Instead, uniform price and quantity procurement is beneficial for the aggregate group surplus if its members are not too heterogeneous and / or the share of rich members is sufficiently high.

We find that a buyer group may not be stable, in the sense that members are worse off than non-members and thus have an incentive to leave. Without transfers between group members, with pure uniform price procurement, poor members always have an incentive to leave. This is not necessarily the case with uniform quantity procurement. Here the buyer group is stable without transfers, except for the case where rich members want to opt out as they are better off with self-procurement. With transfers, the buyer group is stable under uniform pricing as long as poor members buy positive quantities in equilibrium. Under uniform quantity procurement, transfers do not increase the stability of the group as poor members cannot compensate rich members if these are better off outside the group.

In summary, we find that joint procurement can be superior to self-procurement for heterogeneous buyers. Which joint procurement rule is optimal for the buyer group depends on the degree of heterogeneity within the buyer group, the group composition, the production technology and thus scarcity of the good, the demand from outside the buyer

group as well and the feasibility of transfers within the group. Our findings suggest that these factors should be taken into account by any country and the group as a whole when deciding whether to buy jointly. According to our results, the degree of heterogeneity between group members should be sufficiently low for high income countries to benefit individually from the joint procurement under a uniform price and quantity restriction (which can be interpreted as equal quantities on a per-capita basis).[34]

Our theoretical results for this case can be related to the European Unions' COVID-19 vaccine purchases. They underline the assessment of the EU that their procurement strategy is most efficient and fair in terms of allocations [35] if we assess the member states of the EU as countries that are not too heterogeneous.

We do not consider the timely availability of supply in our static model framework which, however, was critical in the case of COVID-19 vaccines. Whereas joint procurement might be superior to self-procurement in terms of price and fairness consideration, it can entail disadvantages in terms of delays due to the coordination processes (e.g., alignment of interests or procurement procedure).This may matter especially for larger and more heterogeneous procurement groups that have limited prior experience regarding the type of procurement, as seen in the EU procurement case. This might also give other self-procuring countries a competitive advantage. If the product is urgently needed and the production capacity is constrained, the time factor should be considered in the decision-making process about the appropriate procurement rule.

In our model the main advantage of joint procurements are the lower prices that group members can obtain. However, this reduces the supplier's profits that are lowest under uniform quantity procurement. Low sales prices make production less profitable and can lead to lower investments in research and development as well as production capacity. Even if we focus on the implications for the demand side, the possible impacts on the supply the supply side should be taken into account in specific cases as well.

Our results contribute to the literature on joint procurement and allow for a formal assessment of certain key claims and concerns of the joint vaccine procurement of the EU and the COVAX initiative. There are indications that joint procurements involving heterogeneous buyers could become a more common strategy in the EU and beyond, not only for health products but also in other areas, such as energy. It might thus be fruitful to extend the model in future research to address additional aspects. These include the consideration of a dynamic setup, which endogenizes capacity decisions by adding another stage at the beginning of the game structure. One could also consider different degrees of negotiation power, different masses of rich and poor countries, a quantity restriction that allows rich members to buy a proportional higher quantity then poor members, and a price cap imposed by the buyer group. So far, we kept the negotiation power constant and did not assume that the mere fact that countries buy jointly as a buyer group increases their negotiation power.

[34] In our model with linear demand and increasing marginal costs, it is sufficient that the demand curve of rich countries is not more than about 25% larger than that of poor countries (see Proposition 3). Joint procurement with only a uniform price restriction can be desirable for both country types for larger degrees of heterogeneity if transfers between rich and poor members are feasible (see Proposition 4).

[35] See Section 1.

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Appendix I

Price discrimination:

We plug the equilibrium quantities and prices derived in Table 1 in Equations (7) and (8) to derive the total consumer surplus and the welfare in Table 5.

		Consumer Surplus (CS^{PD}_{World})	Welfare (W^{PD})
$\kappa = 0$		$\frac{1}{8}(\gamma_L + 1)$	$\frac{3}{8}(\gamma_L + 1)$
$\kappa = 1$	$\gamma_L > \hat{\gamma}^{PD}$	$\frac{\gamma_L(1-2\gamma_L)^2+1}{8(2\gamma_L+1)^2}$	$\frac{\gamma_L(4\gamma_L(3\gamma_L-1)+3)+3}{8(2\gamma_L+1)^2}$

Table 5: Additional market outcomes for price discrimination.

Uniform price:

We plug the equilibrium quantities and prices derived in Table 2 in Equations (7) and (8) to derive the total consumer surplus and the welfare in Table 6.

		Consumer Surplus (CS^{UP}_{World})
$\kappa = 0$	$\gamma_L > \hat{\gamma}_1^{UP}$	$\frac{\gamma_L((3hl+h)\gamma_L-6hl+h+l)+3hl+l}{8(h\gamma_L+l)}$
	$\gamma_L \leq \hat{\gamma}_1^{UP}$	$\frac{1}{8}(1-(l-1)\gamma_L)$
$\kappa = 1$	$\gamma_L > \hat{\gamma}_2^{UP}$	$\frac{\gamma_L(\gamma_L(4\gamma_L((3hl+h)\gamma_L-h(3l+1)+l)-9hl+h-4l)+6hl+h+l)+3hl+l}{8(2\gamma_L+1)^2(h\gamma_L+l)}$
	$1/2 < \gamma_L \leq \hat{\gamma}_2^{UP}$	$\frac{l^2\gamma_L^2-2l^2\gamma_L+l^2-4l\gamma_L^3+4l\gamma_L^2+l\gamma_L-2l+4\gamma_L^3-4\gamma_L^2+\gamma_L+1}{8(l-2\gamma_L-1)^2}$
		Welfare (W^{UP})
$\kappa = 0$	$\gamma_L > \hat{\gamma}_1^{UP}$	$\frac{\gamma_L(h(l+3)\gamma_L+h(3-2l)+3l)+(h+3)l}{8(h\gamma_L+l)}$
	$\gamma_L \leq \hat{\gamma}_1^{UP}$	$\frac{3}{8}(-l\gamma_L+\gamma_L+1)$
$\kappa = 1$	$\gamma_L > \hat{\gamma}_2^{UP}$	$\frac{\gamma_L(\gamma_L(4\gamma_L(h(l+3)\gamma_L-h(l+1)+3l)-3h(l-1)-4l)+h(2l+3)+3l)+(h+3)l}{8(2\gamma_L+1)^2(h\gamma_L+l)}$
	$1/2 < \gamma_L \leq \hat{\gamma}_2^{UP}$	$\frac{5l^2\gamma_L^2-6l^2\gamma_L+3l^2-12l\gamma_L^3+4l\gamma_L^2+3l\gamma_L-6l+12\gamma_L^3-4\gamma_L^2+3\gamma_L+3}{8(l-2\gamma_L-1)^2}$

Table 6: Additional market outcomes for uniform pricing.

Uniform quantity:

We plug the equilibrium quantities and prices derived in Table 3 in Equations (7) and (8) to derive the total consumer surplus and the welfare in Table 7.

		Consumer Surplus (CS^{UQ}_{World})
$\kappa = 0$		$\frac{1}{8}\left((1-2h)\gamma_L + 2h + 1\right)$
$\kappa = 1$	$\gamma_L > 1/2$	$\frac{-2h^3\gamma_L^3+6h^3\gamma_L^2-6h^3\gamma_L+2h^3+9h^2\gamma_L^3-17h^2\gamma_L^2+7h^2\gamma_L+h^2-12h\gamma_L^3+10h\gamma_L^2+6h\gamma_L-4h+4\gamma_L^3-4\gamma_L^2+\gamma_L+1}{8(h\gamma_L-h-2\gamma_L-1)^2}$
		Welfare (W^{UQ})
$\kappa = 0$		$\frac{3}{8}\left(\gamma_L + 1\right)$
$\kappa = 1$	$\gamma_L > 1/2$	$\frac{\gamma_L\left(5h^2+\gamma_L\left(3(h-2)^2\gamma_L-7h(h-2)-4\right)+3\right)-(h-1)(h+3)}{8(-(h-2)\gamma_L+h+1)^2}$

Table 7: Additional market outcomes for uniform quantity.

Figure 3 illustrates efficient rationing.

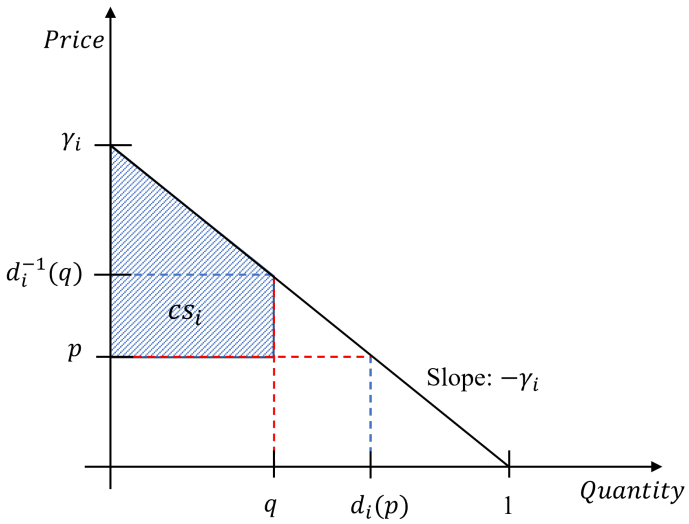

Figure 3: Consumer surplus for rich member countries under uniform quantity procurement under the assumption of efficient rationing.

Appendix II

This appendix contains proofs to the Lemmas and Propositions.

Proof of lemma 1. Solving the system of Equations (10) and (11) under the restriction that all countries buy positive quantities yields the following equilibrium prices and quantities for constant and increasing marginal costs for both country types.
First, we compare the outcomes for $\kappa = 0$ (constant marginal costs). In this case all countries buy a strictly positive quantity for $0 < \gamma_L < 1$ because equilibrium quantities are constant. It holds that $p_H^{PD} = \frac{1}{2} > \frac{\gamma_L}{2} = p_L^{PD}$ and poor countries pay a lower price than rich countries.
Secondly, we compare the outcomes for $\kappa = 1$ (increasing marginal costs). Solving the equilibrium quantity for poor countries in Table 1 at $d_L^{PD} = 0$ yields the critical γ_L-value $\hat{\gamma}^{PD} = \frac{1}{2}$. For $\gamma_L \leq \hat{\gamma}^{PD}$ poor countries buy a zero quantity. Given Assumption 1 we only consider the case $\gamma_L > \hat{\gamma}^{PD}$ at which all country types buy under PD. It holds that $p_H^{PD} = \frac{4\gamma_L+1}{4\gamma_L+2} > \frac{\gamma_L(2\gamma_L+3)}{4\gamma_L+2} = p_L^{PD}$ because $4\gamma_L + 1 > \gamma_L(2\gamma_L + 3)$ for $0 < \gamma_L < 1$. As in the constant marginal costs case rich countries pay a higher price. □

Proof of lemma 2. Solving the system of Equations (13), (14) and (15) under the restriction that all countries buy weakly positive quantities yields the following equilibrium prices and quantities for constant and increasing marginal costs for both country types and the buyer group.
First, we compare the outcomes for $\kappa = 0$ (constant marginal costs). Solving the equilibrium quantity in Table 2 at $q_{LG} = 0$ yields the critical γ_L-value $\hat{\gamma}_1^{UP} = \frac{h-l}{2h} \geq 0$. If $\gamma_L \leq \hat{\gamma}_1^{UP}$ holds, poor member countries do not buy under UP and we obtain $p_H^{UP} = p_G^{UP} = \frac{1}{2} > \frac{\gamma_L}{2} = p_L^{UP}$. Equilibrium prices for poor and rich non-members are unchanged to the PD case with constant marginal costs (see proof of Lemma 1). Rich member countries obtain the same price as rich non-member countries. If $\gamma_L > \hat{\gamma}_1^{UP}$, all types buy positive quantities and it holds that $p_H^{UP} = \frac{1}{2} > p_G^{UP} = \frac{(h+l)\gamma_L}{2(h\gamma_L+l)} > p_L^{UP} = \frac{\gamma_L}{2}$. The equilibrium prices of non-members are unchanged to the case that poor members do not buy and therefore unchanged to the PD case. The uniform price is between these prices.
Secondly, we compare the outcomes for $\kappa = 1$ (increasing marginal costs). We derive $\hat{\gamma}_2^{UP}$ by comparing the profits of the supplier (see Equation (3)) from serving only rich member countries at a higher price to serving both types of countries at a uniform price. These two profits cross only once in the interval $\gamma \in [0.5, 1)$ such that $\hat{\gamma}_2^{UP}$ is unique. To see this note that at the boundary $\gamma_L = 1$, when both country types are identical the supplier optimally serves both types. The lower bound $\gamma_L = 1/2$ is due to Assumption 1. Solving the equilibrium quantity in Table 2 at $q_{LG} = 0$ yields the value $\gamma_L = \frac{\sqrt{5h^2+2hl+l^2}+h-l}{4h} > 0.5$ at which poor member countries buy a quantity of zero. Thus, in the interval $\gamma \in \left[0.5, \frac{\sqrt{5h^2+2hl+l^2}+h-l}{4h}\right]$ it is optimal for the supplier to serve only the rich member countries at a higher price, as the supplier makes zero profits from selling to poor member countries. Above $\gamma_L = 1/4(1+\sqrt{5})$ it is more profitable for the supplier to sell to both member types in any case. Let Δ_π be the difference of the profits, i.e., the profits of the supplier of serving both types minus the profit of serving

only the rich member countries. The derivative of Δ_π has a positive sign in the relevant range$\left[\frac{\sqrt{5h^2+2hl+l^2}+h-l}{4h}, 1/4(1+\sqrt{5})\right]$. There thus exists a unique intersection of the profits at a value of $\hat{\gamma}_2^{UP}$in between $\frac{\sqrt{5h^2+2hl+l^2}+h-l}{4h}$ and $1/4(1+\sqrt{5})$, such that serving all member countries is profitable for $\gamma_L \geq \hat{\gamma}_2^{UP}$ and not serving poor member countries for $\gamma < \hat{\gamma}_2^{UP}$. For $\gamma_L \leq \hat{\gamma}_2^{UP}$ poor member countries do not buy under UP and it holds that $p_H^{UP} = p_G^{UP} = \frac{(l-4)\gamma_L+l-1}{2(l-2\gamma_L-1)} > p_L^{UP} = \frac{\gamma_L(2l-2\gamma_L-3)}{2(l-2\gamma_L-1)}$. Rich countries obtain the same equilibrium price independent of the membership. As above poor non-members pay lower prices as rich countries. If $\gamma_L > \hat{\gamma}_2^{UP}$, all types buy positive quantities and it holds that $p_H^{UP} = \frac{4\gamma_L+1}{4\gamma_L+2} > p_G^{UP} = \frac{\gamma_L(2(2h+l)\gamma_L+h+3l)}{2(2\gamma_L+1)(h\gamma_L+l)} > p_L^{UP} = \frac{\gamma_L(2\gamma_L+3)}{4\gamma_L+2}$. The buyer group has no effect on non-member countries and they obtain the same equilibrium prices as under PD for increasing marginal costs. This results from the total quantity $Q = \frac{\gamma_L}{2\gamma_L+1}$ (see Equation (2)) being unchanged for UP compared to PD due to the linear demand function used as discussed by Varian (2010), page 470-471. □

Proof of lemma 3. Solving the system of Equations (17), (18) and (19) under the restriction that all countries buy weakly positive quantities yields the following equilibrium prices and quantities for constant and increasing marginal costs for both country types and the buyer group.

First, we compare the outcomes for $\kappa = 0$ (constant marginal costs). In this case all countries buy a strictly positive quantity for $0 < \gamma_L < 1$ because equilibrium quantities are constant. It holds that $p_H^{UQ} = \frac{1}{2} > \frac{\gamma_L}{2} = p_G^{UQ} = p_L^{UQ}$. The buyer group and poor non-member countries pay a lower price than rich non-members.

Secondly, we compare the outcomes for $\kappa = 1$ (increasing marginal costs). As the critical value that solves the equilibrium quantity in Table 3 at $q_G^{UQ} = d_L^{UQ} = 0$ is below $1/2$, we only consider the case at which all country types buy under UQ given Assumption 1. It holds that $p_H^{UQ} = \frac{(h-4)\gamma_L-h-1}{2(h-2)\gamma_L-2(h+1)} > \frac{\gamma_L((h-2)\gamma_L-h-3)}{2(h-2)\gamma_L-2(h+1)} = p_G^{UQ} = p_L^{UQ}$ and, as in the constant marginal costs case, rich non-members pay a higher price than the other countries. □

Proof of proposition 1. First, we compare the parametric expressions for the profits under price discrimination and uniform pricing for the different cases of κ and γ to show that price discrimination yields larger profits than uniform pricing. We compare the profits for the supplier for $\kappa = 0$ (constant marginal costs) and $\gamma_L \leq \hat{\gamma}_1^{UP}$, poor member countries do not buy under UP yielding $\pi^{PD} = \frac{1}{4}(\gamma_L+1) > \frac{1}{4}(-l\gamma_L+\gamma_L+1) = \pi^{UP}$. Comparing the profits for the supplier for $\kappa = 0$ if $\gamma_L > \hat{\gamma}_1^{UP}$ yields that $\pi^{PD} = \frac{1}{4}(\gamma_L+1) > \frac{-hl\gamma_L^2+2hl\gamma_L-hl+h\gamma_L^2+h\gamma_L+l\gamma_L+l}{4(h\gamma_L+l)} = \pi^{UP}$.

For $\kappa = 1$ (increasing marginal costs) and $\gamma_L \leq \hat{\gamma}_2^{UP}$ poor member countries do not buy under UP. It holds that $\pi^{PD} = \frac{2\gamma_L^2-\gamma_L+1}{4(2\gamma_L+1)} > \frac{2l\gamma_L^2-2l\gamma_L+l-2\gamma_L^2+\gamma_L-1}{4(l-2\gamma_L-1)} = \pi^{UP}$. Lastly, we compare the profits for the supplier for $\kappa = 1$ and $\gamma_L > \hat{\gamma}_2^{UP}$. If all buy, it holds that $\pi^{PD} = \frac{2\gamma_L^2-\gamma_L+1}{4(2\gamma_L+1)} > \frac{\gamma_L(\gamma_L(-2h(l-1)\gamma_L+h(3l-1)+2l)+h-l)-hl+l}{4(2\gamma_L+1)(h\gamma_L+l)} = \pi^{UP}$.

Secondly, we show that the profits of the supplier under uniform pricing exceeds the profits of uniform quantity. For a proof by contradiction, suppose that the supplier makes larger profits under UQ than under UP. Then there must exist a uniform price charged to the group and a pair of prices charged to the two types outside the group that yields

larger profits than can be achieved under uniform pricing. However, the supplier could charge the same prices under UP which results in a larger quantity sold to the rich group members whenever UQ has any effect at these prices. Thus the supplier can sell a larger quantity at the same prices which may result in a larger profit if prices are above marginal costs. Otherwise, the supplier can increase the prices, if in case of increasing marginal costs, price above marginal costs would not hold for the initial prices. In both cases the firms realizes a larger profit under UP yielding the contradiction. □

Proof of proposition 2. Taking the prices and quantities from Table 1 and substituting these into Equation (4) yields the consumer surpluses for the two country types for PD for constant and increasing marginal costs. Taking the prices and quantities for members from Table 2 and substituting these into Equation (5) yields the consumer surpluses for the two member country types for UP for constant and increasing marginal costs.
First, we compare the outcomes for poor members countries for $\kappa = 0$ (constant marginal costs). If $\gamma_L \leq \hat{\gamma}_1^{UP}$ holds, poor member countries do not buy under UP. These countries will obtain a zero consumer surplus with UP, while they still obtain $cs_L^{PD} = \frac{\gamma_L}{8} > 0$ at these γ_L-values with PD. If $\gamma_L > \hat{\gamma}_1^{UP}$, all types buy positive quantities and it holds that $cs_L^{PD} = \frac{\gamma_L}{8} > \frac{\gamma_L(h\gamma_L+l-h(1-\gamma_L))^2}{8(h\gamma_L+l)^2} = cs_{LG}^{UP}$ because $h(1-\gamma_L) > 0$ holds for $0 < \gamma_L < 1$ and $h \in (0, 1]$. Therefore, UP cannot be a Pareto improvement to PD for constant marginal costs as poor member countries are always worse off under UP.
Secondly, we compare the outcomes for poor members countries for $\kappa = 1$ (increasing marginal costs). For $\gamma_L \leq \hat{\gamma}_2^{UP}$ poor member countries do not buy under UP , these countries obtain a zero surplus with UP, while, for PD, they still obtain $cs_L^{PD} = \frac{\gamma_L(2\gamma_L-1)^2}{8(2\gamma_L+1)^2} > 0$ for $\gamma_L > \frac{1}{2}$ by Assumption 1. For $\gamma_L > \hat{\gamma}_2^{UP}$ all types buy positive quantities, it holds that $cs_L^{PD} = \frac{\gamma_L(2\gamma_L-1)^2}{8(2\gamma_L+1)^2} > \frac{\gamma_L(-2\gamma_L(2h\gamma_L-h+l)+h+l)^2}{8(2\gamma_L+1)^2(h\gamma_L+l)^2} = cs_{LG}^{UP}$, such that poor members have a lower surplus for UP compared to PD. Hence, in both cases of constant and increasing marginal costs, poor member countries are strictly worse off, such that UP is not Pareto superior to PD.
Thirdly, we compare the outcomes for rich members countries for $\kappa = 0$. If $\gamma_L \leq \hat{\gamma}_1^{UP}$ (poor member countries do not buy under UP), $cs_{HG}^{UP} = \frac{1}{8} = cs_H^{PD}$ holds. Therefore, they are only weakly better off in that case. For the case $\gamma_L > \hat{\gamma}_1^{UP}$ (all types buy positive quantities), $cs_H^{PD} = \frac{1}{8} < \frac{(h\gamma_L+l+l(1-\gamma_L))^2}{8(h\gamma_L+l)^2} = cs_{HG}^{UP}$ holds, such that rich members have a strictly higher surplus with UP compared to PD.
Lastly, we compare the outcomes for rich members countries for $\kappa = 1$. If $\gamma_L \leq \hat{\gamma}_2^{UP}$ poor member countries do not buy under UP, rich members are better off with UP compared to PD as $cs_H^{PD} = \frac{1}{8(2\gamma_L+1)^2} < \frac{(1+l\gamma_L-l)^2}{8(2\gamma_L+1-l)^2} = cs_{HG}^{UP}$ holds. For $\gamma_L > \hat{\gamma}_2^{UP}$ all types buy positive quantities and $cs_H^{PD} = \frac{1}{8(2\gamma_L+1)^2} < \frac{(\gamma_L(h-2l\gamma_L+l)+2l)^2}{8(2\gamma_L+1)^2(h\gamma_L+l)^2} = cs_{HG}^{UP}$ holds, that is rich members are strictly better off with UP compared to PD. □

Proof of proposition 3. Taking the prices and quantities from Table 1 and substituting these into Equation (4) yields the consumer surpluses for the two country types for PD for constant and increasing marginal costs. Taking the prices and quantities for the members from Table 3 and substituting these into Equation (5) yields the consumer surpluses for

the two member country types for UQ for constant and increasing marginal costs.
First, we compare the outcomes for poor members countries for $\kappa = 0$ (constant marginal costs). Under PD poor countries and under UQ poor countries and rich members buy a positive quantity for constant marginal cost for all γ_L-values. It holds that $cs_{LG}^{UQ} = cs_L^{PD} = \frac{\gamma_L}{8}$ and poor members are as well off with UQ as with PD.
Secondly, we compare the outcomes for poor members countries for $\kappa = 1$ (increasing marginal costs). Under PD poor countries and under UQ poor countries and rich members buy a positive quantity in any case we consider under Assumption 1. It holds that $cs_{LG}^{UQ} = \frac{\gamma_L((h-2)\gamma_L-h+1)^2}{8(-(h-2)\gamma_L+h+1)^2} > \frac{\gamma_L(2\gamma_L-1)^2}{8(2\gamma_L+1)^2} = cs_L^{PD}$ and poor members are better off with UQ. Therefore, poor members are always weakly better off with UQ compared to PD.
Thirdly, we compare the outcomes for rich members countries for $\kappa = 0$. It holds that $cs_{HG}^{UQ} = \frac{1}{8}(3-2\gamma_L) > \frac{1}{8} = cs_H^{PD}$ because $(3-2\gamma_L) > 0$ for $0 < \gamma_L < 1$. Rich members obtain a higher surplus with UQ compared to PD and UQ is a Pareto improvement to PD for constant marginal costs.
Lastly, we compare the outcomes for rich members countries for $\kappa = 1$. Under two conditions it holds that $cs_H^{PD} = \frac{1}{8(2\gamma_L+1)^2} < -\frac{((h-2)\gamma_L-h+1)\left(2(h-2)\gamma_L^2-5h\gamma_L+3h+5\right)}{8(-(h-2)\gamma_L+h+1)^2} = cs_{HG}^{UQ}$.
The first condition states that $0 < h \leq \frac{4}{7}$ and $\tilde{\gamma_L} < \gamma_L < 1$ has to hold, where $\tilde{\gamma_L}$ is the supremum of $x_2(h)$ in h given $h\epsilon(0, 4/7]$. The function $x_2(h)$ is the second root in x of the polynomial $\mathrm{x}^4(4h^2-16h+16)+\mathrm{x}^3(24-6h^2)+\mathrm{x}^2(16h-3h^2)+\mathrm{x}(4h^2+6h-10)+h^2-3$. The parameter $\tilde{\gamma_L}$ is approximately 0.65. Alternatively, the second condition implies that $\frac{4}{7} < h \leq 1$ and $\frac{1}{2} < \gamma_L < 1$ have to hold. For any l we consider and if one of the conditions is satisfied, rich members obtain a higher surplus with UQ than PD. $\gamma_L = 0.81$ is sufficiently high that rich members are better off with UQ independent on the composition of the group. If that is the case, UQ is a Pareto improvement to PD for increasing marginal costs. □

Proof of proposition 4. Taking the prices and quantities from Table 2 and substituting these into Equation (4) yields the consumer surpluses for the two country types for PD for constant and increasing marginal costs. Taking the prices and quantities for members from Table 2 and substituting these into Equation (5) yields the consumer surpluses for the two member country types for UP for constant and increasing marginal costs. Taking these surpluses and substitute these in Equation (6) yields the aggregate consumer surplus of the buyer group for constant and increasing marginal costs.
First, we compare the aggregate surpluses of the buyer group for $\kappa = 0$ (constant marginal costs). If $\gamma_L \leq \hat{\gamma}_1^{UP}$ holds, poor member countries do not buy under UP. It holds that $CS_{Group}^{UP} = \frac{h}{8} < \frac{1}{8}(h + l\gamma_L) = CS_{Group}^{PD}$. The aggregate surplus of the group will be higher with PD than with UP in that case because $h + l\gamma_L > h$. For $\gamma_L > \hat{\gamma}_1^{UP}$, all buy positive quantities under UP and $CS_{Group}^{UP} = \frac{\gamma_L\left(h^2+4hl\gamma_L-6hl+l^2\right)+4hl}{8(h\gamma_L+l)} > \frac{1}{8}(h + l\gamma_L) = CS_{Group}^{PD}$ holds.
Secondly, we compare the aggregate surpluses of the buyer group for $\kappa = 1$ (increasing marginal costs). For $\gamma_L \leq \hat{\gamma}_2^{UP}$ poor member countries do not buy under UP. It holds that $CS_{Group}^{PD} = \frac{h+l\gamma_L(1-2\gamma_L)^2}{8(2\gamma_L+1)^2} < \frac{h(l\gamma_L-l+1)^2}{8(2\gamma_L+1-l)^2} = CS_{Group}^{UP}$ for $h > \hat{h} = \frac{2l^2\gamma_L-l^2-8l\gamma_L^2+2l+8\gamma_L^3+4\gamma_L^2-2\gamma_L-1}{2l\gamma_L^2-l\gamma_L-2l+4\gamma_L+2}$.
Let $\Delta_{CS_{Group}} = CS_{Group}^{UP} - CS_{Group}^{PD}$ be the difference of the surpluses. The derivative of $\Delta_{CS_{Group}}$ with respect to h has a positive sign in the relevant range $\frac{1}{2} < \gamma_L \leq \hat{\gamma}_2^{UP}$. The

aggregate consumer surplus of the group increases more under uniform pricing than under price discrimination, the higher the share of rich members. For $\gamma_L > \hat{\gamma}_2^{UP}$, all buy positive quantities under UP and $CS_{aggG}^{UP} = \frac{\gamma_L\left(h^2+4l\gamma_L(\gamma_L(4h\gamma_L-4h+l)-2h-l)+6hl+l^2\right)+4hl}{8(2\gamma_L+1)^2(h\gamma_L+l)} > \frac{h+l\gamma_L(1-2\gamma_L)^2}{8(2\gamma_L+1)^2} = CS_{aggG}^{PD}$ holds. The aggregate consumer surplus of the buyer group is larger with UP than with PD. □

Proof of proposition 5. Taking the prices and quantities for members from Table 2 and substituting these into Equation (5) yields the consumer surpluses for the two member country types for UP for constant and increasing marginal costs. Taking the prices and quantities for members from Table 3 and substituting these into Equation (5) yields the consumer surpluses for the two member country types for UQ for constant and increasing marginal costs. Taking these surpluses and substitute these in Equation (6) yields the aggregate consumer surplus of the buyer group for constant and increasing marginal costs. First, we compare the aggregate surpluses of the buyer group for $\kappa = 0$ (constant marginal costs). If $\gamma_L \leq \hat{\gamma}_1^{UP}$ holds, poor member countries do not buy under UP. It holds that $CS_{Group}^{UP} = \frac{h}{8} < \frac{1}{8}\left((l-2h)\gamma_L + 3h\right) = CS_{Group}^{UQ}$. The aggregate surplus is higher under uniform quantity than under uniform pricing procurement. For $\gamma_L > \hat{\gamma}_1^{UP}$, all buy positive quantities under UP and $CS_{Group}^{UP} = \frac{\gamma_L\left(h^2+4hl\gamma_L-6hl+l^2\right)+4hl}{8(h\gamma_L+l)} < \frac{1}{8}\left((l-2h)\gamma_L+3h\right) = CS_{Group}^{UQ}$ holds if $\gamma_L > \frac{l}{2h+3l}$. If γ_L is sufficiently large, uniform quantity procurement yields a higher aggregate surplus for the buyer group than uniform pricing.
Secondly, we compare the aggregate surpluses of the buyer group for $\kappa = 1$ (increasing marginal costs). For $\gamma_L \leq \hat{\gamma}_2^{UP}$ poor member countries do not buy under UP and it can hold that $CS_{Group}^{UP} = \frac{h(l\gamma_L-l+1)^2}{8(l-2\gamma_L-1)^2} < -\frac{((h-2)\gamma_L-h+1)\left(\gamma_L\left(-5h^2+(h-2)(2h-l)\gamma_L+(h-1)l\right)+h(3h+5)\right)}{8(-(h-2)\gamma_L+h+1)^2} = CS_{Group}^{UQ}$. It holds, for instance, if $h = \frac{1}{5}$ and $l = \frac{4}{5}$ and $0.67 \approx \hat{\gamma}_2^{UP} \geq \gamma_L > 0.6$. For approximately $\gamma_L \leq 0.6$ it holds that $CS_{Group}^{UP} > CS_{Group}^{UQ}$ and the aggregate surplus of the group is higher under uniform pricing even if poor members obtain a zero surplus. For $h = \frac{4}{5}$ and $l = \frac{1}{5}$ we obtain $CS_{Group}^{UP} = \frac{h(l\gamma_L-l+1)^2}{8(l-2\gamma_L-1)^2} < -\frac{((h-2)\gamma_L-h+1)\left(\gamma_L\left(-5h^2+(h-2)(2h-l)\gamma_L+(h-1)l\right)+h(3h+5)\right)}{8(-(h-2)\gamma_L+h+1)^2} = CS_{Group}^{UQ}$ and uniform quantity procurement is better than uniform pricing for the group for any $\gamma_L \leq \hat{\gamma}_2^{UP} \approx 0.79$. For $\gamma_L > \hat{\gamma}_2^{UP}$, where all buy positive quantities under UP and it can hold $CS_{Group}^{UP} < CS_{Group}^{UQ}$ with $CS_{Group}^{UP} = \frac{\gamma_L\left(h^2+4l\gamma_L(\gamma_L(4h\gamma_L-4h+l)-2h-l)+6hl+l^2\right)+4hl}{8(2\gamma_L+1)^2(h\gamma_L+l)}$ and $CS_{Group}^{UQ} = \frac{((h-2)\gamma_L-h+1)\left(\gamma_L\left(-5h^2+(h-2)(2h-l)\gamma_L+(h-1)l\right)+h(3h+5)\right)}{8(-(h-2)\gamma_L+h+1)^2}$. It holds, for instance, if $h = \frac{1}{5}$ and $l = \frac{4}{5}$ and approximately $\gamma_L > 0.8$. For $0.67 \approx \hat{\gamma}_2^{UP} < \gamma_L \leq 0.8$ it holds that $CS_{Group}^{UP} > CS_{Group}^{UQ}$ and the aggregate surplus of the group is higher under uniform pricing. For $h = \frac{4}{5}$ and $l = \frac{1}{5}$ we obtain $CS_{Group}^{UP} < CS_{Group}^{UQ}$ with $CS_{Group}^{UP} = \frac{\gamma_L\left(h^2+4l\gamma_L(\gamma_L(4h\gamma_L-4h+l)-2h-l)+6hl+l^2\right)+4hl}{8(2\gamma_L+1)^2(h\gamma_L+l)}$ and
$CS_{Group}^{UQ} = -\frac{((h-2)\gamma_L-h+1)\left(\gamma_L\left(-5h^2+(h-2)(2h-l)\gamma_L+(h-1)l\right)+h(3h+5)\right)}{8(-(h-2)\gamma_L+h+1)^2}$ and uniform quantity procurement is better than uniform pricing for the group with $\gamma_L > \hat{\gamma}_2^{UP} \approx 0.79$.

Taking the prices and quantities for members from Table 2 and substituting these into Equation (5) yields the country-specific surpluses for the buyer group members for UP for constant and increasing marginal costs.

Taking the derivative with respect to l yields the comparative statics if the share of poor member countries, l, changes.

First, we derive how the surplus of member countries changes with l for $\kappa = 0$. If $\gamma_L \leq \hat{\gamma}_1^{UP}$ holds, poor member countries do not buy under UP and the surplus of rich members $cs_{HG}^{UP} = \frac{1}{8}$ is constant in l. If $\gamma_L > \hat{\gamma}_1^{UP}$, all types buy strictly positive quantities and it holds that $\frac{\partial cs_{HG}^{UP}}{\partial l} = \frac{h(\gamma_L-1)\gamma_L((l-h)\gamma_L-2l)}{4(h\gamma_L+l)^3} > 0$ and $\frac{\partial cs_{LG}^{UP}}{\partial l} = -\frac{h(\gamma_L-1)\gamma_L(2h\gamma_L-h+l)}{4(h\gamma_L+l)^3} > 0$. The higher the share of poor members, the higher the surpluses of both members.

Secondly, we derive how the surplus of member countries changes with l for $\kappa = 1$. If poor member countries do not buy under UP, i.e. $\gamma_L \leq \hat{\gamma}_2^{UP}$, $\frac{\partial cs_{HG}^{UP}}{\partial l} = -\frac{\gamma_L(2\gamma_L-1)(l\gamma_L-l+1)}{4(l-2\gamma_L-1)^3} > 0$ holds. Rich members obtain a higher surplus, the higher the share of poor members. For $\gamma_L > \hat{\gamma}_2^{UP}$, all types buy strictly positive quantities and $\frac{\partial cs_{HG}^{UP}}{\partial l} = -\frac{h(\gamma_L-1)\gamma_L\left((h+l)\gamma_L-2l\gamma_L^2+2l\right)}{4(2\gamma_L+1)(h\gamma_L+l)^3} > 0$ and $\frac{\partial cs_{LG}^{UP}}{\partial l} = -\frac{h(\gamma_L-1)\gamma_L\left(-2(h-l)\gamma_L+4h\gamma_L^2-h-l\right)}{4(2\gamma_L+1)(h\gamma_L+l)^3} > 0$ holds. For increasing marginal costs the country-specific surpluses of both member countries increase in l in any case that we consider under Assumption 1.

Taking the derivative with respect to h yields the comparative statics if the share of rich member countries, h, changes.

First, we derive how the surplus of member countries changes with h for $\kappa = 0$. If $\gamma_L \leq \hat{\gamma}_1^{UP}$ holds, poor member countries do not buy under UP and the surplus of rich members $cs_{HG}^{UP} = \frac{1}{8}$ is constant in h. If $\gamma_L > \hat{\gamma}_1^{UP}$, all types buy strictly positive quantities and it holds that $\frac{\partial cs_{HG}^{UP}}{\partial h} = -\frac{l(\gamma_L-1)\gamma_L((l-h)\gamma_L-2l)}{4(h\gamma_L+l)^3} < 0$ and $\frac{\partial cs_{LG}^{UP}}{\partial h} = \frac{l(\gamma_L-1)\gamma_L(2h\gamma_L-h+l)}{4(h\gamma_L+l)^3} < 0$. Both surpluses of the members decreases with in h.

Secondly, we derive how the surplus of member countries changes with h for $\kappa = 1$. If poor member countries do not buy under UP, i.e. $\gamma_L \leq \hat{\gamma}_2^{UP}$, it holds that $cs_{HG}^{UP} = \frac{(l\gamma_L-l+1)^2}{8(l-2\gamma_L-1)^2}$ and $\frac{\partial cs_{HG}^{UP}}{\partial h} = 0$. The surplus of rich members does not change with h. For $\gamma_L > \hat{\gamma}_2^{UP}$ all types buy strictly positive quantities and it holds that $\frac{\partial cs_{HG}^{UP}}{\partial h} = -\frac{l(\gamma_L-1)\gamma_L\left(-(h+l)\gamma_L+2l\gamma_L^2-2l\right)}{4(2\gamma_L+1)(h\gamma_L+l)^3} < 0$ and $\frac{\partial cs_{LG}^{UP}}{\partial h} = \frac{l(\gamma_L-1)\gamma_L\left(-2(h-l)\gamma_L+4h\gamma_L^2-h-l\right)}{4(2\gamma_L+1)(h\gamma_L+l)^3} < 0$. Again both surpluses of the members decreases with in h.

Taking the prices and quantities for members from Table 3 and substituting these into Equation (5) yields the consumer surpluses for the two member country types for UQ for constant and increasing marginal costs. Taking the derivative with respect to l yields the comparative statics if the share of poor group members, l, changes.

First, we derive how the surplus of member countries changes with l for $\kappa = 0$ (constant marginal costs). It holds that $cs_{HG}^{UQ} = \frac{1}{8}(3 - 2\gamma_L)$, $\frac{\partial cs_{HG}^{UQ}}{\partial l} = 0$ and $cs_{LG}^{UQ} = \frac{\gamma_L}{8}$, $\frac{\partial cs_{LG}^{UQ}}{\partial l} = 0$. Both surpluses of the members countries are independent on l with constant marginal costs.

Secondly we derive how the surpluses of member countries change with l for $\kappa = 1$ (increasing marginal costs). Under UQ poor countries and rich members buy a positive quantity in any case we consider under Assumption 1. $cs_{HG}^{UQ} = \frac{-((h-2)\gamma_L-h+1)\left(2(h-2)\gamma_L^2-5h\gamma_L+3h+5\right)}{8(-(h-2)\gamma_L+h+1)^2}$, $\frac{\partial cs_{HG}^{UQ}}{\partial l} = 0$ and $cs_{LG}^{UQ} = \frac{\gamma_L((h-2)\gamma_L-h+1)^2}{8(-(h-2)\gamma_L+h+1)^2}$, $\frac{\partial cs_{LG}^{UQ}}{\partial l} = 0$ holds. As for constant marginal costs both surpluses do not change if the share of poor members changes with increasing marginal costs.

Taking the derivative with respect to h yields the comparative statics if the share of rich group members, h, changes.

First, we derive how the surplus of member countries changes with h for $\kappa = 0$ (constant marginal costs). It holds that $\frac{\partial cs_{HG}^{UQ}}{\partial h} = 0$ and $\frac{\partial cs_{LG}^{UQ}}{\partial h} = 0$. Both surpluses of the members countries are independent on h with constant marginal costs.
Secondly we derive how the surpluses of member countries change with h for $\kappa = 1$ (increasing marginal costs). Under UQ poor countries and rich members buy a positive quantity in any case we consider under Assumption 1. It holds that $\frac{\partial cs_{HG}^{UQ}}{\partial h} = -\frac{(\gamma_L-1)((h+2)\gamma_L-h-3)}{2((h-2)\gamma_L-h-1)^3} > 0$ and $\frac{\partial cs_{LG}^{UQ}}{\partial h} = -\frac{(\gamma_L-1)\gamma_L((h-2)\gamma_L-h+1)}{2((h-2)\gamma_L-h-1)^3} > 0$. Both member countries are better off, the higher the share of rich members within the group.

□

Proof of lemma 4. Taking the prices and quantities for non-members from Table 3 and substituting these into Equation (18) yields the consumer surpluses for the two non-member country types for UQ for constant and increasing marginal costs. Taking the derivative with respect to l yields the comparative statics if the share of poor group members, l, changes.
First we derive how the surplus of non-member countries change with l for $\kappa = 0$ (constant marginal costs). It holds that $cs_H^{UQ} = \frac{1}{8}$, $\frac{\partial cs_H^{UQ}}{\partial l} = 0$ and $cs_L^{UQ} = \frac{\gamma_L}{8}$, $\frac{\partial cs_L^{UQ}}{\partial l} = 0$. Both surpluses are independent on the share of poor members.
Secondly we derive how the surpluses of non-member countries change with l for $\kappa = 1$ (increasing marginal costs). Under UQ poor countries and rich members buy a positive quantity in any case we consider under Assumption 1. It holds that $cs_H^{UQ} = \frac{(h(-\gamma_L)+h+1)^2}{8(-(h-2)\gamma_L+h+1)^2}$, $\frac{\partial cs_H^{UQ}}{\partial l} = 0$ and $cs_L^{UQ} = \frac{\gamma_L((h-2)\gamma_L-h+1)^2}{8(-(h-2)\gamma_L+h+1)^2}$, $\frac{\partial cs_L^{UQ}}{\partial l} = 0$. The surpluses of non-member countries do not change if the share of poor members changes.
Taking the derivative with respect to h yields the comparative statics if the share of rich group members, h, changes.
First we derive how the surplus of non-member countries change with h for $\kappa = 0$. It holds that $\frac{\partial cs_H^{UQ}}{\partial h} = 0$ and $\frac{\partial cs_L^{UQ}}{\partial h} = 0$. As for the share of poor members, the share of rich members has no effect on the surpluses of non-members.
Secondly we derive how the surpluses of non-member countries change with h for $\kappa = 1$. Under UQ poor countries and rich members buy a positive quantity in any case we consider under Assumption 1. It holds that $\frac{\partial cs_H^{UQ}}{\partial h} = \frac{(\gamma_L-1)\gamma_L(h\gamma_L-h-1)}{2(-(h-2)\gamma_L+h+1)^3} > 0$ and $\frac{\partial cs_L^{UQ}}{\partial h} = -\frac{(\gamma_L-1)\gamma_L((h-2)\gamma_L-h+1)}{2((h-2)\gamma_L-h-1)^3} > 0$. Non-member countries are better off, the higher the share of rich members within the group. □

Proof of proposition 7. Taking the prices and quantities for rich members from Table 2 and substituting these into Equation (5) yields the consumer surplus for rich member country types for UP for constant and increasing marginal costs. Taking the prices and quantities for rich non-members from Table 2 and substituting these into Equation (4) yields the consumer surpluses for rich non-member countries under UP for constant and increasing marginal costs.
First, we compare the surpluses of rich countries for $\kappa = 0$ (constant marginal costs). For $\gamma_L \leq \hat{\gamma}_1^{UP}$ poor member countries do not buy under UP and $cs_H^{UP} = \frac{1}{8} = cs_{HG}^{UP}$ holds.

Rich members are as well off as rich non-members under UP. If $\gamma_L > \hat{\gamma}_1^{UP}$, all types buy positive quantities and it holds that $cs_H^{UP} = \frac{1}{8} < \frac{((l-h)\gamma_L-2l)^2}{8(h\gamma_L+l)^2} = cs_{HG}^{UP}$ and rich members are better of than non-members.

Secondly, we compare the surpluses for rich members countries for $\kappa = 1$ (increasing marginal costs). For $\gamma_L \leq \hat{\gamma}_2^{UP}$ poor member countries do not buy under UP and $cs_H^{UP} = \frac{(l\gamma_L-l+1)^2}{8(l-2\gamma_L-1)^2} = cs_{HG}^{UP}$ holds. Rich members are as well off as non-members. If $\gamma_L > \hat{\gamma}_2^{UP}$, all types buy positive quantities and $cs_H^{UP} = \frac{1}{8(2\gamma_L+1)^2} < \frac{(\gamma_L(2l-2l\gamma_L)+2l)^2}{8(2\gamma_L+1)^2(l\gamma_L+l)^2} = cs_{HG}^{UP}$ holds. Rich members are better off than rich non-members.

Thirdly, we compare the surpluses of poor countries for $\kappa = 0$. If $\gamma_L \leq \hat{\gamma}_1^{UP}$ holds (poor member countries do not buy under UP), poor members obtain a zero surplus, while poor non-members obtain $cs_L^{UP} = \frac{\gamma_L}{8} > 0$ at these γ_L-values with UP. If $\gamma_L > \hat{\gamma}_1^{UP}$, all types buy positive quantities and it holds that $cs_L^{UP} = \frac{\gamma_L}{8} > \frac{\gamma_L(2h\gamma_L-h+l)^2}{8(h\gamma_L+l)^2} = cs_{LG}^{UP}$. Poor members are worse off than non-members for constant marginal costs in any case.

Lastly, we compare the surpluses for poor members countries for $\kappa = 1$. If $\gamma_L \leq \hat{\gamma}_2^{UP}$, poor member countries do not buy under UP. They obtain again a zero surplus, while poor non-members obtain $cs_L^{UP} = \frac{(1-2\gamma_L)^2\gamma_L}{8(l-2\gamma_L-1)^2} > 0$ at these γ_L-values with UP. For $\gamma_L > \hat{\gamma}_2^{UP}$ all types buy positive quantities and $cs_L^{UP} = \frac{\gamma_L(2\gamma_L-1)^2}{8(2\gamma_L+1)^2} > \frac{\gamma_L\left(2l-4l\gamma_L^2\right)^2}{8(2\gamma_L+1)^2(l\gamma_L+l)^2} = cs_{LG}^{UP}$ holds. Poor members are worse off than non-members for increasing marginal costs in any case. □

Proof of proposition 8. Taking the prices and quantities for the members from Table 3 and substituting these into Equation (5) yields the consumer surpluses for the two member country types for UQ for constant and increasing marginal costs. Taking the prices and quantities for the non-members from Table 3 and substituting these into Equation (4) yields the consumer surpluses for the two non-member country types for UQ for constant and increasing marginal costs.

First, we compare the outcomes for rich countries for $\kappa = 0$ (constant marginal costs). Under UQ poor countries and rich members buy a positive quantity for constant marginal cost for all γ_L-values. It holds that $cs_H^{UQ} = \frac{1}{8} < \frac{1}{8}(3-2\gamma_L) = cs_{HG}^{UQ}$ and rich members are better off than rich non-members under UQ.

Secondly, we compare the surpluses for rich countries for $\kappa = 1$ (increasing marginal costs). As stated in Lemma 3 under UQ poor countries and rich members buy a positive quantity in any case we consider under Assumption (1). It holds that $cs_H^{UQ} = \frac{(h(-\gamma_L)+h+1)^2}{8(-(h-2)\gamma_L+h+1)^2} < -\frac{((h-2)\gamma_L-h+1)\left(2(h-2)\gamma_L^2-5h\gamma_L+3h+5\right)}{8(-(h-2)\gamma_L+h+1)^2} = cs_{HG}^{UQ}$ if $0 < h \leq 2\left(\sqrt{2}-1\right)$ and $\frac{h^2-2h-1}{(h-2)^2} + \sqrt{\frac{h^2-8h+13}{(h-2)^4}} < \gamma_L < 1$ or if $2\left(\sqrt{2}-1\right) < h \leq 1$ and $\frac{1}{2} < \gamma_L < 1$. Rich members are better off than rich non-members if the share of rich members h is sufficiently high or if the share of rich members is low and the degree of heterogeneity is sufficiently low (i.e., γ_L high).

Thirdly, we compare the surpluses of poor countries for $\kappa = 0$. It holds that $cs_L^{UQ} = \frac{\gamma_L}{8} = cs_{LG}^{UQ}$. Poor countries obtain the same surplus independent on the membership.

Lastly, we compare the surpluses for poor members countries for $\kappa = 1$. $cs_L^{UQ} = \frac{\gamma_L((h-2)\gamma_L-h+1)^2}{8(-(h-2)\gamma_L+h+1)^2} = cs_{LG}^{UQ}$ holds and, as for constant marginal costs, both surpluses are equal. □

Proof of proposition 9. The proof for the case of uniform quantity procurement is provided above the proposition.
For the case of uniform price procurement, let us first derive condition (23). Multiplying the left and right hand side of condition (20) with l and condition (21) with h and aggregating the two conditions yields

$$l \cdot (cs_{LG} + t_L) + h \cdot (cs_{HG} + t_H) \geq l \cdot cs_L + h \cdot cs_H.$$

Substituting for t_L from the rearranged budget constraint $t_L = -h \cdot t_H / l$ yields

$$l \cdot cs_{LG} + h \cdot cs_{HG} \geq l \cdot cs_L + h \cdot cs_H. \tag{24}$$

Dividing both sides of the above condition by $l+h$ yields condition (23) above. To evaluate condition (24) for uniform price procurement, we substitute the parametric expressions the different consumer surpluses.
First, we derive the condition for $\kappa = 0$ (constant marginal costs). If $\gamma_L \leq \hat{\gamma}_1^{UP}$ holds, poor member countries do not buy under UP and condition (24) becomes $\frac{h}{8} < \frac{h}{8} + \frac{l\gamma_L}{8}$. This is true because $l\gamma_L > 0$. Therefore, the condition (24) does not hold and rich members cannot compensate poor members if poor members buy a zero quantity. For $\gamma_L > \hat{\gamma}_1^{UP}$ all buy and condition (24) becomes $\frac{\gamma_L\left(h^2+4hl\gamma_L-6hl+l^2\right)+4hl}{8(h\gamma_L+l)} \geq \frac{1}{8}(h + l\gamma_L)$. The condition holds and rich members can compensate poor members if all buy.
Secondly, we derive the condition for $\kappa = 1$ (increasing marginal costs). If $\gamma_L \leq \hat{\gamma}_2^{UP}$ holds, poor member countries do not buy under UP and condition (24) becomes $\frac{h(l\gamma_L-l+1)^2}{8(l-2\gamma_L-1)^2} < \frac{l(hl-4)\gamma_L^2+(l-2h(l-1)l)\gamma_L+h(l-1)^2+4l\gamma_L^3}{8(l-2\gamma_L-1)^2}$. As for constant marginal costs the condition does not hold. Condition (24) becomes $\frac{\gamma_L\left(h^2+4l\gamma_L(\gamma_L(4h\gamma_L-4h+l)-2h-l)+6hl+l^2\right)+4hl}{8(2\gamma_L+1)^2(h\gamma_L+l)} \geq \frac{h+4l\gamma_L^3-4l\gamma_L^2+l\gamma_L}{8(2\gamma_L+1)^2}$ if $\gamma_L > \hat{\gamma}_2^{UP}$ and all buy. Again as for constant marginal costs rich members can compensate poor members if all buy. □