The role of markets on resource conflicts*

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Abstract

We develop a generalized theory of resource conflict. We demonstrate that the existence of a resource curse (or blessing) relies on two fundamental elements: (i) market conditions; and (ii) the production technology or agents' preferences, depending on the context under study. When resource prices are treated as exogenous, we obtain the conventional result: an increase in the value of the resource rent, due to an increase in its price or its availability (or lower opportunity cost of appropriation), increases conflict. However, when the price of the contestable resource is endogenously determined (i.e., in local markets) or if markets do not exist, we find that the relationship between conflict intensity and resource abundance depends on the production technology or on agents' preferences: conflict can increase when the contestable resource becomes scarcer. Our article therefore identifies a fundamental transmission mechanism in resource conflicts.

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1 Introduction

Violent conflict for the control of resources is a recurrent phenomenon that has received significant scholarly attention (e.g., Blattman and Miguel, 2010). Resource abundance has been shown to constitute a major driver of conflict both empirically (Berman et al., 2017; Crost and Felter, 2020) and theoretically (Garfinkel and Skaperdas, 2007). The argument is straightforward: with more resources people face heightened incentives to fight for them. But do more contested resources always give rise to an increase in harmful conflict? The main channel that scholars have explored relates to resource scarcities reducing the opportunity cost of fighting, thereby encouraging more of it. This channel can explain, for instance, the link between environmental degradation (and thus of farmers' income generating ability) and conflict (e.g., Miguel, Satyanath and Sergenti, 2004). However, there are situations where there has been rising conflict in situations where the object of contention itself has become scarcer. For example, in the context of the Rwandan civil war, Verpoorten (2012) provides evidence of more killings occurring in localities with lower land-to-people ratios, where evidently land was the main asset at stake. Likewise, scholars have shown that fighting for communal land (e.g., in Ethiopia or Kenya) occurs in times of scarcities when land is less fertile because of drought (e.g., van Weezel, 2019; Döring, 2020; Eberle, Rohner and Thoenig, 2020). The mechanisms identified in the literature would say that less resources dampen the incentives to engage in conflict, and so are not able to explain these patterns of conflict. Inspired by this, we develop a model of conflict in which we capture the nature of markets (or lack thereof) and agents' production technology or preferences that both explains the conflict channels identified in the existing literature, and can also elegantly explain heightened conflict in situations of resource scarcity.

Whether the objects of contention are resources to be used as inputs in a production process (e.g., land, oil) or consumables (e.g., bread, cattle), the link between resources and conflict established in the literature focuses on two main effects: a *rapacity effect* and an *opportunity cost effect*. The rapacity effect argues that the value of a contestable resource is a driver of conflict, and if that value increases—either through an increase in its price, or an increase in its quantity—then there are stronger incentives to engage in conflict. The opportunity cost effect, on the other hand, considers the alternative use of resources that would otherwise be directed toward conflict and suggests that if the value of this alternative use increases, for example through an increase in wages or productivity, then effort will be distorted toward these activities and consequently conflict will decline.

The existing literature on conflict usually makes the assumption that conflict takes place in situations where there is a well-defined market for the contested good, and the agents that engage in conflict are price takers in this market. The rapacity and opportunity cost effects referred to above are derived from situations where individuals are interested in maximizing the monetary value of the outcome of conflict, since they can subsequently go to the market and trade (at fixed prices) to achieve their most desirable allocation of this and other goods. While this covers a number of conflict situations[1], there are cases where those engaging in the conflict have significant influence over market prices, or where a market for the contested good does not exist. For example, with weak institutions property rights may fail to be enforced thereby leading to a collapse of markets. Likewise, extreme climate effects may produce food shortages, in turn leading to a breakdown of markets for essential commodities such at wheat, maize, or water. Moreover, for communities that are ill-connected to trade centers, such as geographically isolated areas, or areas connected by poor infrastructure, prohibitive transportation costs may imply that relative prices are locally determined, even if the contested commodity (e.g. diamonds, oil) is traded outside the local market. Can we simply borrow the rapacity and opportunity cost effects established in the literature and translate them to these situations?

As noted, with price-taking markets people satisfy their production or consumption needs by trading in the market, so the aim of conflict is to maximize the scope to do so implying production technologies and individuals' preferences play no role in conflict intensity decisions. However, with no market in which to trade, or when trading decisions influence prices, the outcome of conflict will at least partly influence the final allocation agents achieve of the contested and other goods. Intuitively, therefore, technology and preferences will play a role in conflict decisions and so we need to think more carefully about the determinants of conflict intensity.

In this article, we construct a model that allows us to investigate precisely how technology and preferences play a role in conflict choices. There is a contestable resource available in a given quantity, and people have to decide how to allocate their time between producing a (non-contested) good and engaging in conflict to appropriate the contestable good. We create a general framework that is developed in two directions to encompass a wide range of scenarios: (i) agents are endowed with a production technology whose inputs are the contestable good

[1] This intuitively appealing approach—which identifies the determinants of conflict as resource prices, the availability of contestable resources, and incomes from productive sectors—ties in nicely with the empirical literature. This has sought to use variation in these characteristics of conflict environments, combined with data on conflict, to test the ideas at play (e.g., Dube and Vargas, 2013; Berman et al., 2017; Crost and Felter, 2020). In many situations of conflict—such as minerals, oil, diamonds, drugs, or timber—this framework provides a good structure to think about the issues.

and the produced good; and (ii) individuals derive utility from the consumption of these two goods. We allow for diminishing marginal productivity in the two goods in the first case, and for diminishing marginal utility in the two goods in the second (as well as interactions between the two arguments of the functions).[2] If there is no market, the outcome of this activity determines their final allocation. If there is a market, however, individuals can engage in trade so this allocation determines their budget. Trade will be at fixed prices if prices are exogenously determined by world markets (as in the existing literature), and if prices are endogenously determined in local markets we account for individuals' influence on market prices. By investigating conflict in this way we are able to encapsulate the primary driver of conflict intensity within a wide range of scenarios: those where resources are tradable (with either exogenously or endogenously determined prices); as well those where no market exists to trade resources. This uncovers a new transmission mechanism to explain the underlying incentives behind conflict.

With a market on which the two goods can be traded at fixed prices we derive the standard rapacity and opportunity cost effects, precisely because individuals make conflict decisions with the aim of maximizing the monetary value of conflict. Such will be the case when the contested prize is a marketable input (e.g., oil, minerals) or consumable (e.g., diamonds), and our model is therefore consistent with conventional approaches and empirical findings (e.g., Dube and Vargas, 2013; Berman et al., 2017; Harari and La Ferrara, 2018).

However, in the absence of markets individuals make their conflict decisions based on maximizing their output or their utility from the resulting allocation of contested and produced goods implied by the outcome of conflict. Investigation of this setting shows that technology or preferences are crucial in determining conflict choices: we derive intuitive conditions on technology and preferences that show when the standard rapacity and opportunity cost channels are at work, and when these effects work in the opposite direction. For instance, the rapacity channel in this setting is associated with an increase in the availability of the contested good; depending on technology or preferences this can lead to an increase in conflict (as standard), or a reduction. As such, our model can account for resources being a blessing, rather than a curse; and for scarcity-driven conflict that is not fueled by price increases. The basic intuition is that when, for example, the contested good is scarce and becomes scarcer, people anticipate their production/consumption declining from an already low level. If they have sufficiently diminishing marginal productivity/utility they will care enough about this that

[2]One of the conventional models to study the relationship between resources and conflict can be traced back to Gordon Tullock's (1980) contribution on rent seeking. A generalization of production technologies has been considered by Skaperdas and Syropoulos (1998) and of preferences by Dickson, MacKenzie and Sekeris (2018).

they will distort effort toward conflict in an attempt to recover their production/consumption. Such will be the case when relative land scarcity in the presence of weak institutions and insecure property rights incentivizes farmers and/or pastoralists to fight over the control of this input as shown in, for example, Eberle, Rohner and Thoenig (2020) and McGuirk and Nunn (2020).[3] Regarding conflict over consumables, one can refer to situations of extreme food scarcities leading to the collapse of markets, where studies on conflict support our thesis (Smith, 2014; von Uexkull, 2014; Bagozzi, Koren and Mukherjee, 2017; Koren and Bagozzi, 2017).

In a similar vein, the opportunity cost effect does not necessarily go in the expected direction, depending on the nature of production technology or individuals' preferences. A fall in productivity of the non-contested good could incentivize individuals to increase production efforts, consequently reducing conflict. Koren (2018) establishes a positive causal impact of increased agricultural yields on conflict; although the author does suggest a plausible explanatory mechanism that is akin to the rapacity channel[4], these empirical findings can well be rationalized with our own theoretical findings.

In instances where markets exist and yet clear locally, as is the case if at least one of the two commodities' price is determined locally, we show that conflict can also be heightened by resource scarcities rather than abundance. In such contexts, the relative value of contested resources correlates with, but does not explain conflict. Instead, local scarcities dictate time allocation decisions, which, in turn, modify the value of goods.[5] In other words, while our model identifies a positive association between conflict effort and the *value* of the contestable resource, the underlying mechanism shows that effort reallocation as a result of the availability of the resource drives this change in value (rather than the reverse). This theoretical nuance is far from innocuous when exploring the matter empirically.

Our approach, therefore, highlights that the nature of markets in the setting in which conflict takes place is a key driver of conflict decisions. If no markets exist or the agents that engage in conflict have market power, the results from the literature on conflict that presume markets with fixed prices cannot be translated to these settings. Instead we have to consider

[3]Observe that we are explicitly tying market structure to property rights rather than to institutions generally speaking. Indeed, as shown in McGuirk and Burke (2020), institutions can have an overall mitigating effect on conflict.

[4]The mechanism proposed by Koren (2018) involves armed groups strategically moving where they will be able to feed their troops, especially in contexts of food insecurity (Koren and Bagozzi, 2016), which is compatible with our own theory.

[5]Other scholars have studied resource conflict when accounting for market isolation (Maystadt et al., 2014; Berman and Couttenier, 2015; Castillo, Mejía and Restrepo, 2020).

the nature of production technologies or preferences because if these exhibit sufficiently strong diminishing marginal productivity/utility (which is a very reasonable supposition) the rapacity and opportunity cost channels actually work in the opposite direction. As such, we identify the underlying factors that determine whether resources constitute a curse or a blessing, and whether resource scarcity, in and of itself, can drive more conflict.

In reality, as we have discussed, there are conflict situations where the setting has these characteristics, so developing this understanding is highly important. Table 1 provides a broad taxonomy of market structure for various contestable goods by distinguishing global markets (with fixed prices), local markets, and resources that have no market as well as qualifying the use of the contested goods as an input or a consumable. For example contestable minerals are typically sold on global markets, while land will be traded locally unless property rights are too weak to secure the transactions, thereby implying the absence of a market.[6] The majority of the literature focuses on contestable goods within global markets and, as such, provides explanations for the standard rapacity and opportunity cost effects. Yet as is clear from Table 1, there exists a range of conflict settings where the assumptions of the existing literature are not appropriate but where our model should be applied.

	Contestable goods	
Markets	Consumables	Production inputs
Global Market	Diamonds	Minerals, Oil
Local Market	Potable water	Land, irrigation water (strong property rights)
No Market	Subsistence food	Land, fishing areas (weak property rights)

Table 1: A taxonomy of contestable goods with indicative applications

By investigating the role of markets in resource conflicts we have expanded the range of settings to which the study of resource conflicts can be applied. Our model allows for markets with fixed prices, as the majority of the rest of the literature assumes, but also markets with endogenously-determined prices and where no market exists. Importantly, the standard rapacity and opportunity cost channels found in fixed price settings cannot automatically be applied to these other settings, where the nature of production technologies/preferences will dictate whether they work in the conventional way, or in reverse. As such, our more general model adds to our understanding of resource conflicts. The remainder of the article is organized as follows. We briefly discuss the related literature in the next section. In Section

[6] Although we have provided indicative examples for each aspect, it is also possible these examples—in specific contexts—may overlap between categories.

3 the model is introduced and we analyze the case without markets. Section 4 then explores the effect of markets, and Section 5 extends our results to the case with asymmetric agents. Finally, Section 6 provides some concluding remarks. Proofs of the theoretical results are contained in the appendix.

2 Related literature

This article investigates appropriation of resources using the institutional framework of a strategic contest, where agents invest sunk effort to appropriate a rent. Recently, Dickson, MacKenzie and Sekeris (2018) formulated the idea that higher rents can map into reduced effort in a pure contest setup. While the present contribution also engages an objective function with non-linearities (decreasing marginal productivity/utility and/or production/consumption complementarities) to show that scarcities can incentivize people to fight more intensively, we advance the literature by expanding the framework to include a fundamental aspect of resource conflicts: the role of markets. As our findings show, the nature of markets plays a critical role in explaining the relationship between resource abundance and conflict since players with market power may behave in the exact opposite way they would have acted if they were price-takers.

As our focus is on a multiple-goods/sectors setting, a key methodology is presented by Dal Bó and Dal Bó (2011). They develop a standard Heckscher-Ohlin trade model to which they introduce an appropriative sector. In line with Heckscher-Ohlin predictions, increases in the price of the capital-intensive (labor-intensive) good lead to an increase of the relative remuneration of capital (labor), thus reducing (increasing) the opportunity cost of joining the appropriative sector, and by extension increasing (reducing) conflict intensity. Researchers have provided robust empirical support for both mechanisms identified by Dal Bó and Dal Bó (2011); the rapacity effect (Ross, 2015; Berman et al., 2017; Crost and Felter, 2020), the opportunity cost effect (Miguel, Satyanath and Sergenti, 2004; Brückner and Ciccone, 2010; Hsiang, Burke and Miguel, 2013; Couttenier and Soubeyran, 2014; Hodler and Raschky, 2014; Gawande, Kapur and Satyanath, 2017; Harari and La Ferrara, 2018), or both (Dube and Vargas, 2013).[7] Hence, Dal Bó and Dal Bó (2011)'s theory draws predictions tying prices of resources and wages to conflict consistent with the standard rapacity and opportunity cost effects. We view our model

[7] The literature has taken many directions tying resources to conflict including through price changes (Brückner and Ciccone, 2010; Bellemare, 2015) and the role of poverty (Humphreys and Weinstein, 2008; Do and Iyer, 2010; Bohlken and Sergenti, 2010). There is also an extensive cross-country literature on the resources-civil war nexus with some scholars confirming the rapacity channel (Collier and Hoeffler, 2004; Ross, 2006; Lei and Michaels, 2014), and others questioning the result (Brunnschweiler and Bulte, 2009; Cotet and Tsui, 2013; Bazzi and Blattman, 2014).

as complementary to Dal Bó and Dal Bó (2011): we take a different underlying approach but nest their conclusions in our model, while also considering alternative conflict environments where our conclusions differ.

McGuirk and Burke (2020) expand Dal Bó and Dal Bó (2011)'s theory, by considering the possibility that the same commodity (food) that is produced using some input (land) influences conflict either through an attempt to control the underlying input (*factor conflict*), or through an attempt to control the product itself (*output conflict*). McGuirk and Burke (2020) allows us to understand why price increases may result in more (output) conflict in localities that are mainly consuming the goods, while also accommodating for a (factor) conflict-inducing effect of price reductions as the opportunity cost of conflict is then lower. We complement their study by investigating the endogenous formation of prices in such setups on top of considering the exogenous market case, and—as shown in the analysis—equilibrium predictions can be reversed in such instances. Observe that McGuirk and Burke (2020) consider a concave utility function, as we do, but restrict the consumption bundle to a single good. In our setup, when viewing the contestable good as a consumable, we enrich the analysis by allowing individuals to consume both the contestable and the produced goods, while endowing them with preferences that accommodate consumption complementarities and decreasing marginal utility over the two commodities. Importantly, given the generality of our objective function (whether production function or utility function, depending on the interpretation), our model delivers a novel mechanism that is absent in McGuirk and Burke (2020): more abundant resources can lead to decreases in conflict due to strong diminishing marginal productivity/utility and/or strong production/consumption complementarities.

Further related contributions include Berman, Couttenier and Soubeyran (2021) who show that higher fertilizer prices incentivize poorly endowed farmers to attempt appropriating land as a consequence of their higher input prices. Acemoglu et al. (2012) and Sekeris (2014) propose models where scarcities generate conflict in a dynamic game; with a resource-exporting country trading with a resource-importing one (Acemoglu et al., 2012) or with two contestants involved in a common-pool resource management problem (Sekeris, 2014).

Overall, the existing literature can help explain the rapacity and opportunity effects in a number specific contexts, and we contribute to this literature by expanding the range of settings to which the analysis of conflict can be applied, demonstrating the role of production technology or preferences in the determination of conflict when the setting deviates from the standard 'market with fixed prices' assumption.

3 The model

3.1 Economic environment

Our aim is to set out a parsimonious model to capture the effect of contestable resource shocks in different market settings. To this end, consider an economy in which there is a set of agents $N = \{1, 2, \ldots, n\}$ and two goods—a contestable good r and a non-contestable good y. The key feature of the contestable good is that it is 'lootable', i.e., it can be obtained as a result of conflict (appropriation); we assume that the amount that is locally available is exogenously fixed and given by R.[8] Agents have an endowment of time and make a decision about how much of this time to dedicate to appropriation of the contestable good, with the remainder of their time going to production of the non-contestable good. They may also have access to a market in order to trade their allocation of the contestable and non-contestable goods, where their allocation is determined by their time-allocation choice.

Each agent has a resource of $e^i > 0$ units of time available and has to decide on the number of units $x^i \in [0, e^i]$ of this time to allocate to appropriating the contestable good. The remainder of their time, $l^i = e^i - x^i$ is allocated to producing the non-contestable good according to the constant returns to scale production function $y^i = \alpha^i l^i$. If agent $i \in N$ receives bundle $(r^i, y^i) \in \mathbb{R}^2_+$ they achieve a payoff $v^i(r^i, y^i)$ that we assume to be increasing in both arguments and twice continuously differentiable. We denote by $MRS^i(r^i, y^i) \equiv \frac{v^i_y}{v^i_r}$ the absolute value of the marginal rate of substitution (MRS) between r^i and y^i, and we assume that $MRS^i_r \geq 0$ and $MRS^i_y \leq 0$, which implies $v^i(\cdot, \cdot)$ is quasi-concave.

We consider that the payoff function $v^i(r^i, y^i)$ can take one of two possible forms depending on the setting being considered:

$$v^i(r^i, y^i) \equiv \begin{cases} f^i(r^i, y^i) & \text{if goods are production inputs (non-consumables) or} \\ u^i(r^i, y^i) & \text{if goods are consumables.} \end{cases} \quad (1)$$

$f^i(r^i, y^i)$ is interpreted as a production function, where the contestable good r and the (already produced) non-contestable good y are inputs to production of a final good with diminishing returns from inputs and convex isoquants. $u^i(r^i, y^i)$ can be interpreted as a conventional utility function, where agent i has the ability to directly consume the contestable good r and a non-contestable good y with diminishing marginal utility and convex indifference curves. In both frameworks we can define the marginal rate of substitution, either in terms of consumption $uMRS \equiv \frac{u^i_y}{u^i_r}$ (for the utility case) or in terms of technical substitution $fMRS \equiv \frac{f^i_y}{f^i_r}$ (for the

[8] This does not preclude the contestable good from having been produced (so we are not restricting attention to conflict only over natural resources), but for simplicity we consider this production to be external to our model.

production case). For simplicity of exposition we initially assume all agents are symmetric with $e^i = e$, $v^i(\cdot,\cdot) = v(\cdot,\cdot)$ and $\alpha^i = \alpha$ for all $i \in N$, but extend the analysis to heterogeneous agents in Section 5.

We suppose that appropriation of the contestable good is governed by a Tullock (1980) share contest, so agent i's appropriated share of the contested good is given by

$$\pi^i(x^i, X^{-i}) = \begin{cases} \frac{x^i}{x^i+X^{-i}} & \text{if } x^i + X^{-i} > 0 \text{ or} \\ \frac{1}{n} & \text{otherwise,} \end{cases} \tag{2}$$

where $X^{-i} = \sum_{j \in N \setminus \{i\}} x^j$. Given a vector of appropriation effort choices $\mathbf{x}$, the quantities of the contestable and non-contestable goods allocated to agent i are given by

$$\hat{r}^i = \pi^i(x^i, X^{-i})R, \text{ and}$$
$$\hat{y}^i = \alpha[e - x^i].$$

We allow for the possibility of agents engaging in a market to trade the contestable and non-contestable goods, as well as considering settings in which there is no market. Accordingly, we consider three alternative institutional frameworks:

1. where no market exists between the contestable and non-contestable goods so the allocation from the contest is the final allocation;
2. where a market exists but market clearing is at a higher geographical level so prices are (locally) exogenous (i.e., a partial equilibrium setting); and
3. where a local market exists between the contestable and non-contestable goods, in which prices are determined endogenously with agents' choices to locally clear the market (i.e., a general equilibrium setting).

In each case, we seek a (symmetric) Nash equilibrium of the simultaneous-move game of complete information that is played.

3.2 Equilibrium with non-market contestable goods

If there is no market in which to trade the contested and non-contested goods, the outcome of the contest gives each individual's final allocation. This is relevant in settings where the individuals that engage in conflict genuinely care about what they get out of it, not because they will then trade these goods on markets, but because this is what will be available for either direct consumption or production of a final good.

In these contexts, individuals can be seen as choosing their level of effort to maximize their payoff given the contest technology, i.e.,

$$\max_{x^i \in [0,e]} v^i(\hat{r}^i, \hat{y}^i) \text{ s.t. } \hat{r}^i = \pi^i(x^i, X^{-i})R \text{ and } \hat{y}^i = \alpha[e - x^i].$$

The two constraints can be combined into an outcome possibilities frontier (OPF) of allocations of the contested and non-contested goods that an individual can achieve by engaging in the contest (for given actions of the other contestants). This takes the form

$$\hat{r}^i = \frac{e - \hat{y}^i/\alpha}{e - \hat{y}^i/\alpha + X^{-i}} R, \tag{3}$$

the absolute value of the slope of which is the marginal rate of transformation (not to be confused with the marginal rate of technical substitution of production of the final good that we denoted $fMRS$):

$$MRT = \frac{X^{-i}}{[e - \hat{y}^i/\alpha + X^{-i}]^2} \frac{R}{\alpha}. \tag{4}$$

Considering this problem in (y^i, r^i)-space, as observed within Figure 1, it is straightforward to deduce that individuals will seek to choose their level of effort to equalize their MRS with the MRT. A symmetric Nash equilibrium is therefore characterized by

$$MRS(R/n, \alpha[e - x^*]) = \frac{n-1}{n^2} \frac{R}{\alpha x^*}.$$

Using this relationship, we can deduce the effect on equilibrium effort when there is an increased abundance of contested resources (R increases; the rapacity channel) and when there is an increase in productivity (α increases; the opportunity cost channel). We begin by investigating the rapacity channel.[9]

Proposition 1. *In the absence of a market between the contested and non-contested goods, an increase in the stock of the contested good R distorts effort in the symmetric Nash equilibrium toward (away from) appropriation activities iff*

$$\eta \equiv \frac{rMRS_r}{MRS} < (>) 1.$$

Proposition 1 illustrates that an increase in the stock of the contestable good has an ambiguous effect on the level of appropriation effort. In particular, how appropriation effort changes with the availability of the contestable good depends on the r-elasticity of the MRS. To observe this, consider, in particular, the effect on the optimality condition when R increases keeping the contest effort fixed at the old x^*. The MRS changes by $\frac{1}{n} MRS_r = \frac{1}{R} rMRS_r$; and the MRT changes by $\frac{n-1}{n^2} \frac{1}{\alpha x^*} = \frac{1}{R} MRS$ (using the optimality condition). Now, if the MRT changes

[9] Proposition 1 parallels Dickson, MacKenzie and Sekeris (2018, Proposition 2) that studies the effect of increasing the contested rent in a contest setting.

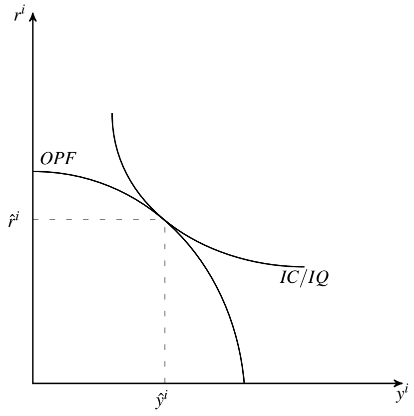

Figure 1: The choice of contestable and non-contestable goods under a non-market setting, where $\hat{r}^i$ and $\hat{y}^i$ denote the allocation of the contested and non-contested goods, with IC denoting an indifference curve, IQ an isoquant, and OPF the outcome possibilities frontier.

by more than the MRS then the equilibrium will involve a smaller $\hat{y}$ and consequently larger x^*. This is represented in Figure 2 (a). In this case, an increase in R expands the OPF and preferences or the production technology are such that the MRT increases by more than the MRS. Thus the agent's optimal choice of $(\hat{y}, \hat{r})$ moves from point a to point a', so there is an increase in appropriation time x^*. Conversely, if preferences or the production technology are such that the MRT changes by less than the MRS then the new equilibrium will involve a larger $\hat{y}$ and therefore smaller x^*. This is observed in Figure 2 (b) with the optimal bundle moving from point a to point a' with an associated decrease in appropriation time. As such, when the amount of the contested good, R, increases, the effort dedicated to contesting this good will increase (decrease) if and only if $MRS > (<) rMRS_r$: conflict intensity in the presence of more contestable resources therefore depends on the nature of the production technology or preferences.

Proposition 1, then, advances our knowledge of the rapacity channel. If the r-elasticity of the MRS is inelastic then we obtain the conventional rapacity channel: an increase in the stock of the contestable good results in increased appropriation effort. Whereas when the r-elasticity exceeds one we find the reverse: an increase in the stock of the contestable good results in a *decrease* in appropriation effort. How this is determined is fundamentally driven by the production technology (for the production case) or preferences (for the consumption case).

Consider the application to contestable production inputs. In such a case $fMRS = \frac{f_y}{f_r}$, $fMRS_r = \frac{f_r f_{ry} - f_y f_{rr}}{[f_r]^2}$ and so $\eta = r\frac{f_r f_{ry} - f_y f_{rr}}{f_r f_y}$. As such, higher f_{ry} (i.e., stronger production complementarities) and/or lower (more negative) f_{rr} (i.e., stronger diminishing marginal returns)

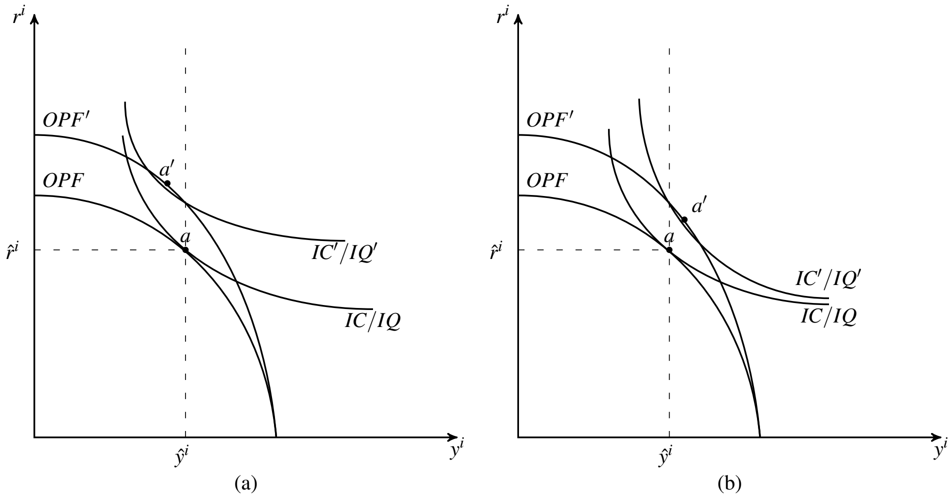

Figure 2: The effects of an increase in the contestable good, R. In case (a) the marginal rate of transformation increases more than the increase in the marginal rate of substitution and there is an increase in appropriation time (decrease in $\hat{y}$). In case (b), the marginal rate of transformation increases less than the marginal rate of substitution and there is a decrease in appropriation time.

are more conducive to an r-elastic $fMRS$ giving rise to an increase in conflict when contested resources become scarcer. In the presence of increased scarcity individuals anticipate they will have less of the contested good as an input; with strong diminishing marginal returns and/or strong complementarities this will lead to a substantial reduction in final good output so in order to reduce the impact they direct more effort toward conflict to mitigate the effect on their allocation of the contested good. A prime example of contestable production inputs with no markets is land in the context of weak property rights, which is typically not traded since ownership is not guaranteed, where the other non-contested input is labor. In this setting a natural assumption is that there are strong diminishing returns and, indeed, complementarities; several empirical studies have identified a causal link from scarcities to conflict, consistent with our findings (Verpoorten, 2012; van Weezel, 2019; Eberle, Rohner and Thoenig, 2020).

Similar scarcity-driven conflict may also occur for contestable consumables. If there is a higher u_{ry} (i.e., stronger complementarities between consumables) and/or lower (more negative) u_{rr} (i.e., stronger diminishing marginal utility) then this is more conducive to an r-elastic $uMRS$. The intuition is similar: if the availability of the contested resource declines individuals anticipate their allocation of it reducing, and if they have strong diminishing marginal utility or consumption complementarities they anticipate a substantial reduction in utility, incentivizing them to distort effort toward conflict to increase their allocation and mitigate the effect. It is useful to connect these findings with real-world situations of scarcity-driven conflict in the absence of markets. Urban food riots, for example, are a recurring phenomenon throughout the developing world, which have also been widely observed in Western countries (at earlier stages of development). Food riots have taken place in urban settings in times of scarcity-driven price spikes (Arezki and Brückner, 2011; Bellemare, 2015; Gustafson, 2020). Such high prices result in poor individuals being *de facto* excluded from the market (Serulnikov, 1994), so it is reasonable to consider that they resort to acquiring food through conflict. Our model is well-designed for capturing the incentives agents face in this setting as the food in question is used for consumption (and not for trading or as production inputs) and rioters' income-generating activity can reasonably be considered unrelated to food production when focusing on urban settings. Given the alignment of the setting with this version of our model—and the likely feature that individuals will have strong diminishing marginal utility at these sub-subsistence levels of food consumption—our prediction is that increased food scarcity will drive more conflict among looters, which we find to be a very reasonable prediction but one that contrasts with a standard rapacity effect argument translated (incorrectly) to this setting (that would imply a positive relationship between the availability of the contested resource and conflict).

Note that conventional models of conflict typically impose linear marginal valuation of the contested good. As such they fail to explain these empirical realities, since food scarcities in such settings will then always result in lower incentives to violently appropriate food, and higher incentives to devote time to the alternative activity. The same holds true for general equilibrium models à la Grossman (1991) or Dal Bó and Dal Bó (2011), either because of the assumed perfect substitution between the contestable and produced good (Grossman, 1991), or because of the setting assuming the existence of markets and prices (Dal Bó and Dal Bó, 2011).

In the absence of markets (and therefore prices) the value to an individual of the contested good is given by the product of their allocation of the good r and its shadow price $\frac{1}{MRS}$, which is, of course, determined endogenously. From an established equilibrium, if R increases then the change in an agent's valuation of their allocation is given by $\frac{r}{R}\frac{MRS-rMRS_r}{MRS^2}$, the sign of which is determined by the r-elasticity of the MRS; it being positive if $\eta < 1$ and negative if $\eta > 1$. As such, our condition on preferences/production technology—that determines whether conflict increases or decreases in the presence of more contested resources—is exactly that which governs whether agents see those resources as more or less valuable as their abundance increases. As resources become more abundant, conflict might decline because agents' do not value these additional resources highly. Likewise, our model identifies that when resources become scarcer, agents will allocate more effort to contesting them and conflict will intensify if agents place a higher value on these scarce resources.

We now turn our attention to the opportunity cost channel.

Proposition 2. *In the absence of a market between the contested and non-contested goods, an increase in productivity α distorts effort in the symmetric Nash equilibrium away from (toward) appropriation activities iff*

$$\xi \equiv -\frac{yMRS_y}{MRS} < (>) 1.$$

Proposition 2 illustrates that increases in the productivity of the non-contestable good has ambiguous effects on the level of appropriation effort. In particular if the y-elasticity is inelastic then increases in productivity result in a reduction in appropriation effort, as with the conventional opportunity cost channel. Whereas, if the y-elasticity exceeds one then we obtain the opposite: an increase in productivity results in an increase in appropriation effort. Note that $MRS_y = \frac{v_r v_{yy} - v_y v_{ry}}{[v_r]^2}$ and therefore $\xi = y\frac{v_y v_{ry} - v_r v_{yy}}{v_r v_y}$ so higher v_{ry} and/or more negative v_{yy} is more conducive to an elastic MRS. So the production technology and preferences are again at the heart of the conflict response to an increase in the opportunity cost of the alternative use of resources.

To summarize the findings of this section, recall that the standard result via the rapacity channel is that if there is less available of the contestable resource then there will be less conflict. Furthermore, when productive efficiency of the alternative use of resources decreases, effort will be distorted away from production and there will be more conflict via the opportunity cost channel. In our model these same results hold if the marginal rate of substitution is, respectively, r-inelastic and y-inelastic. However, the reverse will be true if either there is sufficiently strong diminishing marginal utility/productivity in the contested and non-contested goods, respectively, or if there are strong consumption/production complementarities between the two goods (so the r-elasticity (resp. y-elasticity) exceeds one).

4 The inclusion of markets

In the previous section we focused on the transmission mechanism between conflict and contestable goods in the absence of a market. In this section, we now allow for a market between the contested and non-contested goods. We show how the ability of individuals to trade interacts with our previous transmission mechanism to generate outcomes. As we will see, this depends on whether individuals are price takers, or whether markets clear locally and individuals account for the effect of their actions on the price.

4.1 Equilibrium with exogenous price formation

If there is a market between the contestable and non-contestable goods, and that market clears at a higher geographical level, then we may consider that both goods can flow in and out of the local economy and that actions in the local economy have no influence on the relative price of the contested good. In this case, an individual's allocation from the contest determines the goods available for them to trade in the market at fixed prices. As such, individuals can be seen as choosing their market allocation to maximize their payoff subject to a linear budget constraint where the budget is given by the value of the allocation from the contest.

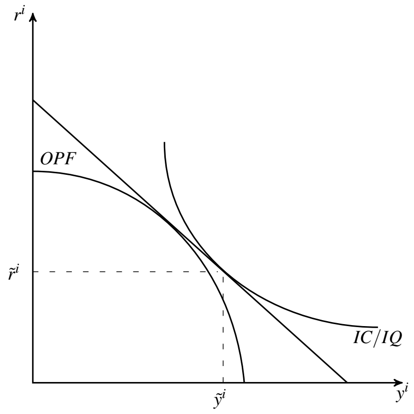

Figure 3: In a market with exogenous prices each individual chooses the point on their OPF to maximize their budget. They then trade on the market to maximize their payoff at $(\tilde{r}^i, \tilde{y}^i)$, with IC denoting an indifference curve and IQ an isoquant.

Let $(\tilde{y}^i, \tilde{r}^i)$ represent the market allocation of the non-contested and contested goods for individual i. Then each individual's optimization problem is simply

$$\max_{\tilde{r}^i, \tilde{y}^i, x^i \in [0,e]} v^i(\tilde{r}^i, \tilde{y}^i) \text{ s.t. } \bar{\phi}\tilde{r}^i + \tilde{y}^i \leq \bar{\phi}\frac{x^i}{x^i + X^{-i}}R + \alpha[e - x^i],$$

where $\bar{\phi} > 0$ is the fixed relative price of the contested and non-contested goods.

Given that individuals can trade at fixed prices, each individual will seek to secure an outcome from the contest that gives them the 'best' budget constraint, which involves maximizing the value of the outcome of the contest. As such, in choosing their effort each individual will seek to

$$\max_{x^i \in [0,e]} \bar{\phi}\frac{x^i}{x^i + X^{-i}}R + \alpha[e - x^i].$$

The necessary and sufficient first-order condition (since the objective function is readily confirmed to be strictly concave) is given by

$$\frac{X^{-i}}{[x^i + X^{-i}]^2}\bar{\phi}R - \alpha = 0.$$

Therefore, in the symmetric Nash equilibrium,

$$x^* = \frac{n-1}{n^2}\frac{\bar{\phi}R}{\alpha}.$$

From this explicit solution we find in the case of exogenous prices:

$$\frac{\mathrm{d}x^*}{\mathrm{d}R} = \frac{n-1}{n^2}\frac{\bar{\phi}}{\alpha} > 0,$$
$$\frac{\mathrm{d}x^*}{\mathrm{d}\alpha} = -\frac{n-1}{n^2}\frac{\bar{\phi}R}{\alpha^2} < 0, \text{ and}$$
$$\frac{\mathrm{d}x^*}{\mathrm{d}\bar{\phi}} = \frac{n-1}{n^2}\frac{R}{\alpha} > 0.$$

As such, a greater value of contested goods (either from an increase in their availability or an increase in price), or a reduction in productivity, will give rise to an increase in effort dedicated to appropriation, as summarized in the following proposition.

Proposition 3. *In the presence of a market between the contested and non-contested goods in which prices are exogenously determined, an increase in the stock of the contested good (R) or an increase in the relative price of the contested good ($\bar{\phi}$) unambiguously distort effort in the symmetric Nash equilibrium toward appropriative activity, while an increase in productivity of the non-contested good (α) unambiguously distorts effort away from appropriative activity.*

This confirms that within our framework, if there is a market for the contested and non-contested goods and individuals are price-takers, then the conventional rapacity and opportunity cost effects are unambiguously at work. These effects are observed because individuals want to maximize the monetary value of what they receive as this determines their budget constraint for trading in the market, and when the contested resource is more valuable, either because of more abundance or because of higher prices, achieving this commands more effort. The production technology and preferences are not at work in determining effort choices because individuals can adjust to their desired allocation in the market; when they appropriate the contestable good, they simply want to maximize their scope for adjustment on the market.

A number of real-world applications can be described within this exogenous price market setting. The aim of many conflicts is to appropriate storable resources for which there are markets, such as oil, minerals, and lumber. The empirical evidence in the literature is consistent with our prediction of the standard rapacity and opportunity cost effects (Berman et al., 2017; Harari and La Ferrara, 2018). In the case of Colombia, for example, Dube and Vargas (2013) empirically find that increases in the price of oil (i.e., the contested rent) boosts conflict whereas higher coffee prices (i.e., the non-contested good) have a conflict-reducing effect.

4.2 Equilibrium with endogenous price formation

We now turn to study the case where the individuals engaging in conflict have market power and thus the market price forms endogenously. Here we consider that the market is isolated and so clears locally, and those individuals that engage in conflict are substantial on the scale of the market and therefore influence market prices. For simplicity of exposition, we assume that only those individuals that engage in the conflict engage in the market.[10]

We envisage that the (relative) price (of the contested good) in the market is set by a Walrasian auctioneer whose objective is to clear the market for the contested good. The supply of this is fixed at R, and the auctioneer understands the demand for the contested good from individual agents as a function of the price. These individual demands can be ascertained by considering the demand from each agent for the contested good following the auctioneer making a price announcement, after which agents choose their desired allocation.

We denote this chosen allocation $\check{r}^i(\phi)$, which will be the solution to

$$\max_{r^i,y^i} v^i(r^i, y^i) \text{ s.t. } \phi r^i + y^i \leq \phi \frac{x^i}{x^i + X^{-i}} R + \alpha[e - x^i],$$

and is therefore characterized by

$$\check{r}^i(\phi) = \{r^i : \check{l}^i(r^i, \phi) \equiv MRS^i(r^i, \phi \frac{x^i}{x^i + X^{-i}} R + \alpha[e - x^i] - \phi r^i) - \frac{1}{\phi} = 0\}. \quad (5)$$

Market clearing thus requires that the auctioneer sets the price such that the aggregation of these demands is equal to the fixed supply of the contested good:

$$\sum_{i=1}^{n} \check{r}^i(\phi) = R.$$

Now, should agent i consider changing their demand for the contested good, they anticipate that the auctioneer will change the price to maintain market clearing. As such, they see the price as being influenced by their choice of r^i according to the relationship

$$\tilde{\phi}^i(r^i) = \{\phi : \tilde{l}^i(\phi, r^i) \equiv r^i + \sum_{j \neq i} \check{r}^j(\phi) - R = 0\}. \quad (6)$$

Note that the outcome of the contest is determined in the same way as before, so $\hat{y}^i = \alpha[e - x^i]$ and $\hat{r}^i = \frac{x^i}{x^i + X^{-i}} R$. In engaging in the contest, anticipating that they can also engage in trade in the market but where they influence the market price, each individual can be seen

[10] A straightforward extension would allow us to capture a situation where there are other individuals that also participate in the market but not in the conflict, but where nevertheless the individuals engaging in the conflict have market power (for example, by assuming the presence of a competitive fringe in the market). Thus our focus here is on situations in which the individuals that engage in conflict have influence on market prices.

as solving the problem

$$\max_{r^i, y^i, x^i \in [0,e]} v^i(r^i, y^i) \text{ s.t. } y^i + \tilde{\phi}^i(r^i) r^i \leq \alpha[e - x^i] + \tilde{\phi}^i(r^i) \frac{x^i}{x^i + X^{-i}} R.$$

Inspection of the constrained optimization problem reveals that an agent's contest effort choice only influences the available budget for trade in the market. As such, contest effort will be chosen to maximize the available budget (noting that the price is not fixed but determined by actions). The budget is $\alpha[e - x^i] + \tilde{\phi}^i(r^i) \frac{x^i}{x^i + X^{-i}} R$ and maximizing through a choice of x^i requires $-\alpha + \tilde{\phi}^i(r^i) \frac{X^{-i}}{[x^i + X^{-i}]^2} R = 0$, which implies

$$1/\tilde{\phi}^i(r^i) = \frac{X^{-i}}{[x^i + X^{-i}]^2} \frac{R}{\alpha}. \tag{7}$$

Individuals, then, will choose their allocation via trade in the market to equate their MRS with the absolute value of the slope of the budget constraint. Since the budget constraint is implicitly defined by $\alpha(e - x^i) + \tilde{\phi}^i(r^i) \frac{x^i}{x^i + X^{-i}} R - y^i - \tilde{\phi}^i(r^i) r^i = 0$, the implicit function theorem then implies

$$MRS^i(r^i, y^i) = \frac{1}{\tilde{\phi}^i(r^i) + \tilde{\phi}^{i\prime}(r^i)[r^i - \hat{r}^i]}.$$

Now, in order for the market to clear in an equilibrium with symmetric players we must have $r^i = \hat{r}^i$. The slope of the budget constraint, therefore, must be equal to $1/\tilde{\phi}^i(r^i)$ and so (7) implies that at the optimal allocation in the equilibrium (with symmetric players) the MRS must be equal to $\frac{n-1}{n^2 x^*} \frac{R}{\alpha}$, which is precisely the MRT at the equilibrium in the no markets case. As such, the equilibrium in the case of endogenous price formation is characterized by

$$MRS(R/n, \alpha[e - x^*]) = \frac{n-1}{n^2} \frac{R}{\alpha x^*},$$

which is exactly the same as the condition characterizing the equilibrium with no markets, and therefore, Propositions 1 and 2 apply equally in this case.

The intuition regarding the equivalence of results between the non-market scenario and the one featuring markets with endogenous prices is the following. With endogenous prices, the optimal effort allocation must be such that the marginal rate of transformation equals the rate at which one can exchange goods via the market—while accounting for the individuals' market power—otherwise a profitable adjustment of effort allocation would exist. Likewise the marginal rate of substitution needs to equal the rate at which one can exchange goods via the market so as to exclude profitable trades. Combined, these features of the equilibrium imply that the marginal rate of substitution will be equal to the marginal rate of transformation at equilibrium. Since we here assume symmetric agents (which is relaxed in the next section), no trade ultimately happens in the market because symmetry implies all agents would want the same thing: agents anticipate this and achieve their final allocation through conflict, just as in the no markets case.

In this setting it is important to observe the relationship between the agents' valuation of the contestable good, $r^i\phi$, and the time allocated to conflict. Since the equilibrium price is $\frac{n^2}{n-1}\frac{\alpha x^*}{R}$ and therefore the equilibrium value of an agent's allocation of the contested good is $\frac{n}{n-1}\alpha x^*$, it follows that in situations where there is increased scarcity of the resource *and* conflict increases, both the price and the value increase: conflict therefore *correlates* with value, but how value is determined in non-market and endogenous price settings is driven by preferences and, in particular, whether the r-elasticity exceeds one or not, as this determines conflict intensity.

Here, again, one may connect our result to real-world patterns. Berman and Couttenier (2015) show, with micro-econometrically grounded analysis of data, that geographical remoteness in Sub-Saharan Africa reduces the influence of global shocks (e.g., an increase in prices of exported commodities) on localized conflict, which is consistent with the idea that market isolation means prices are locally formed. There is no better example of an isolated market than Easter Island (Matthew and Gaulin, 2001) which, prior to being connected to the rest of the world in 1722, was the archetype of an autarkic economy. Easter Islanders were organized in hierarchical clans that interacted peacefully until a major ecological depletion produced important scarcities. Analyses of the settlements' middens and of oral traditions conclude that the food scarcities became so important that this lead the way for cannibalism. In 1680, as the situation had reached dramatic levels of deprivation, "society collapsed in an epidemic of civil war" (Diamond, 2005, p109).

4.3 Mixed market power

Our approach to capturing market power considers that the economy under consideration is isolated, so both the contested and non-contested goods are locally available in fixed quantities and agents supply and demand choices for both goods have a substantial impact on the price. An alternative framework could consider that agents have market power in the market for only one of these commodities, while being a price-taker in the other. A natural interpretation is that agents have market power in the locally-produced non-contested good, and while the locally available contested amount of the contested good is fixed, it can be traded on global markets at a price that agents treat as fixed.

The basic intuition governing the response of conflict to a shock in the availability of the contested resource is as follows. With fully exogenous prices, if the contested good becomes scarcer then agents anticipate their allocation as a result of conflict declining, so re-orient their efforts to producing the non-contested good knowing that they can then trade at fixed prices to achieve their desired allocation. With fully endogenous prices, the story is markedly different: when the contested good becomes scarcer agents again anticipate their allocation from conflict will decline, and so also anticipate that they will want to acquire relatively more through the market, which will have the effect of increasing the price. If their effect on the price is substantial then, rather than trading through the market, they prefer to move closer to their desired final allocation of the contested good through conflict, prompting an increase in the intensity of conflict. Of course, as we have noted, with symmetric agents no trade actually takes place, but agents nevertheless anticipate their effect on the market (with heterogeneous agents, that we consider in the next section, trade does take place).

In a situation of a mixed market where the contested good is traded at fixed prices and agents influence the price of the non-contested good, we can reason that the same intuition that relates to fully endogenous markets applies here as well. If agents anticipate their allocation of the contested good as a result of conflict declining, they will anticipate selling more of the non-contested good on the market in order that they can buy more of the contested good. But this will lower the price (of the non-contested good), and if this reduction is substantial the agent will prefer to acquire the contested good through conflict rather than through the market, again prompting an increase in conflict intensity. As such, the influence of preferences/production technologies on conflict intensity permeates wherever the agents that engage in conflict have market power.

5 Heterogeneous agents

For simplicity we have so far considered that agents are symmetric. In this section we explore the model when agents are heterogeneous to demonstrate that, while the analysis is considerably more complicated, similar conditions that govern the conflict response to a change in the stock of the contested good are at work here as well. We first extend our basic analysis of conflict with no markets to the heterogeneous agents case, and then look at the case with markets and endogenous price formation (the case with fixed prices is straightforward).

5.1 Conflict with no markets and heterogeneous agents

In the case with no markets, in a Nash equilibrium each agent may be seen as choosing their contest effort to

$$\max_{x^i \in [0,e^i]} v^i \left(\frac{x^i}{x^i + X^{-i}} R, \alpha^i [e^i - x^i] \right).$$

The first-order condition governing an interior best response is thus

$$MRS^i\left(\frac{x^i}{x^i+X^{-i}}R, \alpha^i[e^i-x^i]\right) - \frac{x^{-i}}{[x^i+X^{-i}]^2}\frac{R}{\alpha^i} = 0.$$

Rather than working with best responses and levels of effort, we instead consider each agent's share of the aggregate effort $\sigma^i \equiv x^i/X$ that is consistent with a Nash equilibrium in which the aggregate effort is X. Defined on the same domain for each (heterogeneous) player, we can then find an equilibrium aggregate effort as being a value of X where the sum of these shares equals one. Replacing X^{-i} with $X - x^i$ and x^i with $\sigma^i X$ in the first-order condition allows us to define a player's share function which, accounting for the fact that effort cannot exceed the endowment of time, takes the form $\check{s}^i(X;R) = \min\{\sigma^i, e^i/X\}$ where σ^i is the solution to

$$\check{l}^i(\sigma^i, X; R) \equiv MRS^i(\sigma^i XR, \alpha^i[e^i - \sigma^i X]) - [1-\sigma^i]\frac{R}{\alpha^i X} = 0. \tag{8}$$

The properties of share functions are most easily deduced by envisaging the intersection of the two components of the first-order condition (plotted as functions of σ^i): $MRS^i(\sigma^i XR, \alpha^i[e^i - \sigma^i X])$ (which is increasing according to the assumed properties of MRS^i); and $[1-\sigma^i]\frac{R}{\alpha^i X}$ (which is decreasing)). The monotonicity properties imply there is a single solution to the first-order condition. Inspection of the two components of the first-order condition allows us to conclude that $\check{s}^i(X;R) \to 1$ as $X \to 0$, and the assumed properties of MRS^i imply share functions are strictly decreasing in X.

There is a Nash equilibrium when $\check{L}(X,R) \equiv \check{S}(X;R) - 1 = 0$ where $\check{S}(X;R) \equiv \sum_{i=1}^n \check{s}^i(X;R)$. The aggregation of share functions will exceed 1 when X is close to zero, and will be at most 1 by definition when X is equal to $\sum_{i=1}^n e^i$. As such, by the intermediate value theorem there is an $X \in (0, \sum_{i=1}^n e^i]$ where $\check{S}(X;R) = 1$. Since the aggregate share function inherits the property that it is strictly decreasing from individual share functions, there will be exactly one such X, so there is a unique Nash equilibrium. We write $\check{X}(R)$ for this aggregate effort when the contested resource is available in amount R.

We now want to investigate how the equilibrium changes if the amount of the contested resource changes. To do so we assume an interior equilibrium where all agents use some, but not all, of their time endowment in engaging in conflict. The implicit function theorem applied to the equilibrium identification condition implies

$$\check{X}'(R) = -\frac{\check{L}_R}{\check{L}_X}.$$

Since $\check{L}_X = \sum_{i=1}^n \check{s}^i_X$ and we have deduced that $\check{s}^i_X < 0$ for each i, $\text{sgn}\{\check{X}'(R)\} = \text{sgn}\{\check{L}_R\}$.

Now, $\check{L}_R = \sum_{i=1}^{n} \check{s}^i_R$ and the implicit function theorem applied to (8) gives

$$\begin{aligned}\check{s}^i_R &= -\frac{\check{l}^i_R}{\check{l}^i_{\sigma^i}} \\ &= -\gamma^i \left[\sigma^i X MRS^i_r - [1-\sigma^i]\frac{1}{\alpha^i X}\right] \\ &= -\frac{\gamma^i}{R}[r^i MRS^i_r - MRS^i]\end{aligned}$$

where $\gamma^i \equiv 1/\check{l}^i_{\sigma^i} = 1/\left[XRMRS^i_r - \alpha^i X MRS^i_y + \frac{R}{\alpha^i X}\right] > 0$ and the last line utilizes the first-order condition that implies $[1-\sigma^i]\frac{R}{\alpha^i X} = MRS^i$. As such, we can deduce that equilibrium aggregate effort and the contested rent move in opposite directions iff

$$\check{L}_R < 0 \Leftrightarrow \sum_{i=1}^{n} \gamma^i [r^i MRS^i_r - MRS^i] > 0.$$

Sufficient (but not necessary) for this to hold is $r^i MRS^i_r - MRS^i > 0$ for all agents (the same condition as in the homogeneous agents case), but we can still have the result if this is not true for some agents, so long as the aggregate condition holds.

Note that our deductions here are about the equilibrium aggregate effort. It must, of course, be the case that some agents' effort decreases for the aggregate to decrease, but we are not concluding that all agents' effort decreases. Since individual equilibrium effort is given by $\check{x}^i = \check{s}^i(\check{X};R)\check{X}$, while we know that under the stated conditions $\check{X}$ decreases, the change in an agent's share is given by $\check{s}^i_X \check{X}' + \check{s}^i_R$ which is not necessarily negative, so we could have that equilibrium effort increases for some agents as the aggregate effort declines.

5.2 Endogenous markets with heterogeneous agents

We next turn to consider a model of endogenous markets with heterogeneous agents. When there is a market, conflict choices determine the initial allocation of the contested and non-contested goods, and agents can then trade away from this initial allocation using their resources to transact in the market. With endogenous price formation agents anticipate their behavior in the market as this will influence the price, as well as act accordingly in the conflict setting to determine their initial allocation.

In contrast to the case of homogeneous players, by allowing for heterogeneous players we observe trade in the market will take place. However, as we will show, there remain similarities between agents' conflict responses to a change in the availability of the contested good.

Taking into account that an agent's actions influence the price according to (6), the optimization problem agents face in the presence of a market with an endogenously determined price is therefore

$$\max_{r^i,y^i,x^i\in[0,e^i]} v^i(r^i,y^i) \text{ s.t. } \tilde{\phi}^i(r^i)r^i + y^i \le \tilde{\phi}^i(r^i)\frac{x^i}{x^i+X^{-i}}R + \alpha^i[e^i - x^i].$$

We are interested in agents' conflict responses to a change in the availability of the contestable good. Since x^i only directly influences the budget, in equilibrium agents can be seen as choosing their x^i to maximize this budget, the first-order condition governing which is given by

$$-\alpha^i + \tilde{\phi}^i(r^i)\frac{X^{-i}}{[x^i+X^{-i}]^2}R = 0.$$

Again, rather than working with best responses and levels of effort, we consider each agent's share of the aggregate effort by replacing X^{-i} with $X - x^i$ and x^i with $\sigma^i X$ in the first-order condition that allows us to define a player's share function. This takes the form $\tilde{s}^i(X;R) = \min\{\sigma^i, e^i/X\}$ where σ^i is the solution to

$$\tilde{l}^i(\sigma^i, X; R) \equiv -\alpha^i + [1-\sigma^i]\frac{\tilde{\phi}^i(r^i)R}{X} = 0,$$

from which we derive an explicit solution

$$\tilde{s}^i(X;R) = \min\left\{1 - \frac{\alpha^i X}{\tilde{\phi}^i(r^i)R}, \frac{e^i}{X}\right\}. \tag{9}$$

From this explicit solution we conclude that $\tilde{s}^i(X;R) \to 1$ as $X \to 0$ and that it is strictly decreasing in $X > 0$.

There is a Nash equilibrium with aggregate effort X when $\tilde{L}(X;R) \equiv \tilde{S}(X;R) - 1 = 0$ where $\tilde{S}(X;R) \equiv \sum_{i=1}^n \tilde{s}^i(X;R)$. Since the aggregate share function exceeds 1 when X is close to 0, is no larger than 1 when $X = \sum_{i=1}^n e^i$, and is strictly decreasing in X, there is a unique Nash equilibrium and we write $\tilde{X}(R)$ for the equilibrium aggregate effort when the contested resource is available in amount R.

We now want to investigate how the equilibrium changes if the amount of the contested resource changes, and to do so we again assume an interior equilibrium. The implicit function theorem applied to the equilibrium identification condition implies

$$\tilde{X}'(R) = -\frac{\tilde{L}_R}{\tilde{L}_X}.$$

Since $\tilde{L}_X = \sum_{i=1}^n \tilde{s}^i_X$ and from (9) we see that $\tilde{s}^i_X = -\frac{\alpha^i}{\tilde{\phi}^i(r^i)R} < 0$, $\text{sgn}\{\tilde{X}'(R)\} = \text{sgn}\{\tilde{L}_R\}$. Now, $\tilde{L}_R = \sum_{i=1}^n \tilde{s}^i_R$ and differentiation of (9) gives

$$\tilde{s}^i_R = \frac{\alpha^i X}{[\tilde{\phi}^i(r^i)R]^2}\left[\tilde{\phi}^i(r^i) + R\frac{\mathrm{d}\tilde{\phi}^i(r^i)}{\mathrm{d}R}\right].$$

Now, implicit differentiation of (6) gives

$$\begin{aligned}\frac{\mathrm{d}\tilde{\phi}^i(r^i)}{\mathrm{d}R} &= -\frac{\tilde{l}^i_R}{\tilde{l}^i_\phi} \\ &= \frac{1}{\sum_{j\neq i} \check{r}^{j\prime}}.\end{aligned}$$

Implicit differentiation of (5) gives

$$\check{r}^{i\prime} = -\frac{\check{l}^i_\phi}{\check{l}^i_{r^i}}$$

where $\check{l}^i_{r^i} = MRS^i_r - \phi MRS^i_y > 0$ under our assumptions. Exploring the numerator, we find

$$\begin{aligned}\check{l}^i_\phi &= [\sigma^i R - r^i]MRS^i_y + \frac{1}{\phi^2} \\ &= \frac{1}{\phi}[\phi[\sigma^i R - r^i]MRS^i_y + MRS^i] \\ &= \frac{1}{\phi}[MRS^i + y^i MRS^i_y - \alpha^i[e^i - x^i]MRS^i_y] \\ &> \frac{1}{\phi}[MRS^i + y^i MRS^i_y]\end{aligned}$$

where the second line uses the first-order condition $MRS^i = \frac{1}{\phi}$, the third line comes from adding and subtracting $\alpha^i[e^i - x^i]MRS^i_y$ and noting that $y^i = \phi[\sigma^i R - r^i] + \alpha^i[e^i - x^i]$, and the inequality is by virtue of the fact that $\alpha^i[e^i - x^i]MRS^i_y < 0$ by assumption. Given this, a necessary condition for demand for r to be decreasing in its price (taken as a parameter), implied by $\check{l}^i_\phi > 0$, is $MRS^i + y^i MRS^i_y \geq 0$, which we henceforth assume.

With this in hand, we can write

$$\tilde{s}^i_R = \frac{\alpha^i X}{[\tilde{\phi}^i(r^i)R]^2}\left[\tilde{\phi}^i(r^i) + \frac{R}{\sum_{j\neq i} \frac{\frac{1}{\phi^i(r^i)}[MRS^j + y^j MRS^j_y - \alpha^j[e^j - x^j]MRS^j_y]}{MRS^j_r - \phi^i(r^i)MRS^j_y}}\right].$$

In general, evaluating this expression, along with $\sum_{i=1}^n \tilde{s}^i_R$ to determine the sign of $\tilde{X}'(R)$, is complicated due to there being numerous heterogeneous agents.

However, let us focus on the two-player case with agents i and j, and explore the conditions under which the aggregate contest effort is declining in the contested rent. With two agents

$$\begin{aligned}\tilde{s}^i_R &= \frac{\alpha^i X}{[\phi R]^2}\left[\phi - R\frac{\check{l}^j_{r^j}}{\check{l}^j_\phi}\right] \\ &= \frac{\alpha^i X}{\check{l}^j_\phi[\phi R]^2}[\phi \check{l}^j_\phi - R\check{l}^j_{r^j}].\end{aligned}$$

As such, since $\check{l}^j_\phi > 0$ under our assumption that $MRS^j + y^j MRS^j_y \geq 0$, $\tilde{s}^i_R < 0$ if and only if

$\phi \breve{l}^j_\phi - R\breve{l}^j_{r^j} < 0$. Now,

$$\phi \breve{l}^j_\phi - R\breve{l}^j_{r^j} = \phi[\sigma^j R - r^j]MRS^j_y + \frac{1}{\phi} - R[MRS^j_r - \phi MRS^j_y]$$
$$= \phi[\sigma^j R + R - r^j]MRS^j_y + MRS^j - RMRS^j_r.$$

As such, if $MRS^j - RMRS^j < 0$, which is implied by $MRS^j - r^j MRS^j_r < 0$, then $\tilde{s}^i_R < 0$; and if this is true for both agents then we will have $\tilde{X}'(R) < 0$. Thus, the same condition outlined in Proposition 1—that the r-elasticity of the MRS exceeds 1—combined with an additional assumption that the y-elasticity of the MRS is inelastic (i.e., $MRS^i + y^i MRS^i_y \geq 0$, that ensures the market works in a sensible way when trade takes place) governs the conflict response of agents to a change in the contested rent.

In the presence of a market, agents choose their conflict effort to maximize their available budget, anticipating the effect of their trade in the contested good to achieve their desired allocation on the price. If the contested good's availability increases, the agent anticipates a lower price due to abundance, but also increased demand from the other agent. If the impact on the price, which is all driven by the other agent's preferences, is such that the value of the contested good, ϕR, declines, then the agent reduces their conflict intensity.

6 Conclusion

In this article we develop a framework that focuses on the primitive drivers of resource conflict. We hypothesize that individuals may base their appropriation and production decisions on the expected input or consumption bundle this decision will generate. We demonstrate that if the contested and produced goods can be traded at exogenously set prices, the standard results of the literature on the rapacity and opportunity cost effects hold here as well. The intuition is that the markets will incentivize individuals to maximize the market value of the goods they obtain, independently of their production technology or preferences, since this will in turn result in the highest possible budget that can be allocated to purchasing goods and optimizing their well-being (production or direct consumption). As such, the presence of markets with exogenously set prices gives rise to the conventional predictions that a higher value of the contestable good and/or a lower opportunity cost of fighting both incentivize individuals to increase conflict effort at the expense of productive effort.

In the absence of markets, the picture is starkly different. In such situations, individuals' appropriation and production decisions will exclusively be driven by their production technology or preferences, depending on the setup considered. Depending on the production technology or preferences, then, a host of outcomes may be obtained, including ones where the conventional predictions are reversed and the rapacity and opportunity cost mechanisms operate in reverse: scarcer contestable resources and/or better production possibilities can result in higher conflict intensity. The basic intuition is that when, for example, the contested resource is scarce and becomes scarcer, people anticipate their production/consumption (depending on the setup) declining from an already low level. If they have sufficiently diminishing marginal productivity/utility they will care enough about this that they will distort effort toward conflict in an attempt to recover their production/consumption. The same holds true with sufficiently complementary inputs/consumables. Increased scarcity of one good will incentivize individuals to increase effort in obtaining it so as not to lose out on the complementarities in production/consumption.

We demonstrate that (roughly) the same conditions ruling non-market settings are verified in the presence of markets with locally formed prices, i.e., in general equilibrium settings whether players are symmetric or asymmetric. In such instances the prices will indeed adjust to reflect individuals' production technology or preferences and, consequently, scarcer contestable resources and/or more profitable productive activities could generate both more conflict and a higher relative value of the contestable resource because of the associated price adjustment. Importantly, the increased relative value of contestable resources is provoked by the individuals' effort reallocation towards conflict, rather than being the cause of increased fighting. This article, then, highlights the importance of production technology, preferences and markets for understanding the link between scarcities and resource conflicts.

Appendix

Proof of Proposition 1. Effort in the symmetric Nash equilibrium is characterized by

$$l(x^*, R, \alpha) \equiv MRS(R/n, \alpha[e - x^*]) - \frac{n-1}{n^2}\frac{R}{\alpha x^*} = 0, \tag{10}$$

with

$$l_{x^*} = -\alpha MRS_y + \frac{n-1}{n^2}\frac{R}{\alpha[x^*]^2} > 0 \text{ and}$$
$$l_R = \frac{1}{n}MRS_r - \frac{n-1}{n^2}\frac{1}{\alpha x^*}.$$

Using the implicit function theorem,

$$\frac{\mathrm{d}x^*}{\mathrm{d}R} = -\frac{l_R}{l_{x^*}},$$

and so we deduce, by multiplying the expression for l_R by R and utilizing the first-order condition, that

$$\frac{\mathrm{d}x^*}{\mathrm{d}R} > (<)0 \Leftrightarrow rMRS_r - MRS < (>)0 \Leftrightarrow \eta \equiv \frac{rMRS_r}{MRS} < (>)1.$$

□

Proof of Proposition 2. Recall that effort in the symmetric Nash equilibrium is characterized by $l(x^*, R, \alpha) = 0$ (defined in (10)). The implicit function theorem implies

$$\frac{\mathrm{d}x^*}{\mathrm{d}\alpha} = -\frac{l_\alpha}{l_{x^*}},$$

in which

$$l_\alpha = [e - x^*]MRS_y + \frac{n-1}{n^2}\frac{1}{\alpha^2 x^*}.$$

By multiplying the expression for l_α by α and utilizing the first-order condition, we deduce that

$$\frac{\mathrm{d}x^*}{\mathrm{d}\alpha} > (<)0 \Leftrightarrow yMRS_y - MRS < (>)0 \Leftrightarrow \xi^i \equiv \frac{yMRS_y}{MRS} < (>)1.$$

□

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