Credit Market Development and Resource Extraction: Evidence from Global Fisheries

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Abstract

The rapid expansion of credit markets has fueled economic development but could have also contributed to the decline of global common pool resources. This article evaluates the impact of credit market development on resource extraction using a dynamic model with property rights uncertainty over resources and new data on catches, stock sizes and property rights security of the world's commercial fisheries. Our theory predicts that credit market development reduces harvesting costs and induces more resource harvesting if property rights are weak. In contrast, if property rights are strong the positive effect of credit market development on the discounted value of future resource stocks can counterbalance the impact on harvesting costs leading to more conservative resource harvesting. Our empirical findings that credit market development increases resource harvesting under insecure property rights but reduces resource harvesting under secure property rights support these theoretical predictions. The results therefore suggest that strengthening property rights over natural resources can reverse the negative impact of financial development on resource conservation.

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1 Introduction

Many of the words common pool resources have declined over the last decades causing high economic losses (Costello et al. 2016; Arnason et al. 2017), carbon emissions that amplify climate change (Baccini et al. 2012; Harris et al. 2012) and an erosion of global biodiversity (Maxwell et al. 2016; Tilman et al. 2017). Among the main causes for declining common pool resources are insecure property rights over resources (Costello et al. 2008; Stavins 2011) combined with economic development that increases resource demand as well as the harvesting capacity of the resource harvesters (Taylor 2011; Alix-Garcia et al. 2013). Financial markets play an important role for economic development and have expanded rapidly around the world (Levine 2005; Beck et al. 2010). Financial markets are important for economic development because they facility the efficient allocation of production factors. However, in the absence of regulation to internalize common pool externalities, they may lead to overinvestment in common pool resource harvesting and to further resource degradation. Financial development also facilitates the efficient allocation of consumption over time and therefore reduces discount rates as a consequence of lower borrowing costs. Lower discount rates are generally associated with more conservative resource harvesting (Clark 1973, 1990) and may therefore reduce degradation of global common pool resources. As both effects of credit market development on resource harvesting draw in opposite directions it is a priory unclear how credit market development affects the status of common pool resources.

The current paper makes two contributions. First, it provides the first large-scale empirical evidence on the impact of credit market development on resource extraction. Second, it shows analytically and empirically how the effect of credit market development on resource extraction depends on the property rights security over resources.

In the theoretical section of the paper we analyze a model with credit rationing and insecure property rights over a resource stock. The theoretical results show that increasing borrowing limits and declining interest rates have qualitatively similar impacts on resource extraction. The results show further, that the effect of credit market development on harvesting costs dominates under insecure property rights, leading to increased resource extraction. Under secure property rights, the effect of credit market development on harvesting costs is counteracted by an effect on discounting which leads to ambiguous predictions for the impact of credit market development on resources under secure property rights.

Testing the impact of credit market development on resource extraction in relation to property rights security empirically is complicated by three factors. First, resource harvest is often resource stock size dependent. Resource degradation can therefore cause declining harvest levels despite increasing harvesting effort. Using harvest levels to measure resource extraction is therefore misleading. Second, property rights security responds to the status of the resource stock as regulators may try to halt resource degradation by increasing property rights security. Not taking the response of regulation to the resource status into account leads to biased estimates. Third, measuring the impact of credit markets on resource use is confounded by the response of the whole economy to credit market development. Credit market development can spur investment and economic growth, which increases the demand for resources as well as the opportunity costs of resource extraction. Not controlling for changes in demand and the opportunity cost of resource use can further bias the estimates.

In the empirical part of the paper we use novel data on fish catches, fish stocks sizes and property rights security for the vast majority of the words commercial fisheries over the period from 1960 to 2015 combined with indicators of credit market development and macroeconomic performance to estimate the impact of credit market development on resource use under different levels of property rights security. These novel data also allow us to address the difficulties listed above.

First, the data on stock sizes allow us to measure resource harvesting relative to resource stock size, commonly referred to as fishing mortality in the context of the fishery. Fishing mortality corresponds to fishing effort in the widely applied Schaefer harvesting model (Clark 1990) and controls directly for changes in resource abundance. Increasing fishing mortality therefore implies increasing fishing effort independent of the stocks size.

Second, we use the timing of the introduction of Exclusive Economic Zones (EEZs) combined with a rule of law index to measure property rights security over fish stocks. While the implementation of the EEZs gave countries the legal right to establish property rights over marine resources, the rule of law index measures the ability of countries to enforce these rights. Since the EEZs resulted from the United Nations Convention on the Law of the Sea and they cover all marine resource including minerals and fossil fuels, the timing of their implementation can be viewed as exogeneous to the status of individual fisheries. In a robustness check we further weight the index by the inverse of the number of countries harvesting a fish stocks which measures the biological constraint on establishing property rights over mobile resources. The weight measures the ability of countries to establish the rights over resource stocks that can migrate between EEZs.

Third, to describe credit market development we use the lending interest rate to the private sector and, following for example Levine et al. (2000) and Aghion et al. (2014), the volume of total credit to the private sector as an alternative measure of credit market development. While lending interest rates measure the opportunity costs of capital directly, changes in the volume of credit to the private can be interpreted as changes in borrowing constraints. However, even an experimental setup could not separate the direct effects of credit market development on resource harvesting from its indirect effects through economic development or the economic opportunities of fishermen (see e.g. Galor and Zeira (1993)). We therefore control for GDP levels in linear and squared form to control for changes in resource demand and the opportunity costs of resource harvesting that may be correlated with credit market development through economic growth. Further, while fishermen may respond to credit market development through investment in harvesting capital under open access, it may be the government that sets the harvesting limits under secure property rights over resources. However, Costello and Grainger (2018) show that the fishermen influence the regulators decision in their favor. To further test for the independence of the regulatory decision we use the interest rate on government bonds in a further robustness test that reflect the opportunity costs of capital for governments.

The empirical results on the impact of credit market development on resource harvesting generally confirm the theoretical predictions. A one percent reduction of the lending interest rate increases the harvesting rate of fish stocks under open access by 0.10 %. In contrast, the same reduction of the interest rate reduces the harvest rate by 0.15 % for fish stocks with secure property rights. The results using the volume of credit to the private sector as a measure of credit market development are qualitatively similar. A one percent increase of the volume of credit to the private sector increases the harvesting rate of fish stocks under open access by 0.12 percent but reduces the harvesting rate of stocks with secure property rights by 0.29 %. Lastly, a reduction of the interest rate on government bonds by 1 % has no statistically significant impact on resource harvesting under open access but reduces the harvesting rate of fish stocks with secure property rights by 0.23 %. Our results show further that increasing property rights security from open access tp fully secure property rights reduces resource harvesting by about 20 %. These findings are in line with the prediction that credit market development increases resource harvesting under open access and that it reduces resource harvesting under secure property rights. The results further show that resource harvesting responds to government bonds interest rates when property rights are strong but not when property rights are weak. In a next step we use these estimates to simulate the impact of a drop in global interest rates to US levels (3.25 %) and an increase of property rights security to fully secure levels affect global fisheries. The results of the simulation show that reducing interest rates to 3.25 % has almost no impact on global fisheries. The reason for the lack of impact is that the positive and the negative effect of credit market development on resource extraction cancel out under intermediate levels of property rights security. However, changing only property rights or property rights and credit markets simultaneously has a large effect on global fisheries and reduce harvesting rates and also overfishing by 20 or 25 % respectively. The findings of our study therefore suggest that increasing property rights security over resources can reverse the negative impact of economic development on global common property resources.

Resource economists have long considered discount rates as an important factor for determining optimal resource management and environmental conservation. Faustmann (1849) showed as early as the 19th century that interest rates determine the optimal cutting age of forest trees while Hotelling (1931) formulated the rule for optimal resource extraction as a function of the interest rate almost a century ago. Clark (1973) showed further that high interest rates render the extinction of slow growing animal populations economically optimal. The ongoing debate about optimal climate policies also focuses to a large extent on discount rates (e.g. Arrow et al. (2013)). Compared to the large literature on discounting and resource use, few studies consider the impact of credit constraints on resource extraction. Tahvonen (1998) and Tahvonen et al. (2001) show in a theoretical framework that the forest harvesting decision under credit rationing depends on the forest owners preferences and is not determined by the prevailing interest rate.[1] Noack et al. (2018) show further that credit market development can reduce resource extraction under open access when increased investment in outside options raise the opportunity costs of fishing.[2] The current paper contributes to this discussion on the impact of credit market development on resource management by showing a) that increasing borrowing limits and declining interest rates have qualitatively similar effects on resource extraction and b) that the effect of credit market development on resource extraction depends critically on property rights security. The main contribution of the paper are, however, the empirical result. We are only aware of very few studies that explore the relation of credit markets and the environment empirically. While Andersen (2016) shows that credit market development can increase investment in new technologies that

[1]See also Koskela (1989) and Kuuluvainen (1990) on theoretical treatments on the impact of credit rationing on forest management and Amacher et al. (2009) for a summary of the impact of credit market imperfections and forest management.

[2]See Barbier et al. (2016) for theoretical treatment of economic growth, resource use and credit constraints.

offset the emissions from increased production, Assunção et al. (2013) show that loans which are tied to environmental standards are successful in reducing deforestation in the Brazilian Amazon.[3] Although these papers are also concerned with the environmental impact of credit market development their proposed mechanisms, their environmental indicators and their scale is very different from the current paper. Our paper is further related to the large literature on the impact of property rights security on investment and resource management (see for example Besley (1995), Bohn and Deacon (2000), Jacoby et al. (2002), Costello et al. (2008), Copeland and Taylor (2009), Liscow (2013) and Costello and Grainger (2018)). To our knowledge, only the paper by Costello et al. (2008) estimates the impact of property rights security on resource use on a global scale. In differences to Costello et al. (2008) who estimate the impact of fisheries management on the probability of fisheries collapse, we use an exogenous variation in property rights security to identify the effects of property rights security on resource conservation.

The paper proceed as follows. Section 2 uses the theoretical framework to derive testable predictions. Section 3 presents the data, specifies the empirical model, presents the results and discusses their robustness. Section 4 concludes.

2 Theoretical framework

In this section we develop a simple model to predict the impact of credit market development on resource use under insecure property rights. The model captures the effect of credit market development on the opportunity cost of capital and on discounting the income stream from future resource use. We introduce depreciable harvesting capital following Clark et al. (1979) and Singh et al. (2006) to capture the effect of credit markets on the opportunity costs of harvesting capital. To model credit market development we take a simple and parsimonious approach. Developing countries have often low borrowing limits (in the absence of credit market these would be zero) and high interest rates (see Banerjee and Duflo (2010) and the summary statistics of this article). We therefore assume that credit market development can be characterized by increasing borrowing limits as in Deaton (1991) and declining interest rates. Both aspects of credit market development lead to lower discount rates as we will show below.

We model the resource user as an infinitively lived representative household that uses a com-

[3] Quaas et al. (2012) and Teh et al. (2015) infer from observed harvesting rates about the implicit discount rates of fishermen or the fishing industry but they do not relate these observations to property rights security or changes in observed market interest rates.

mon pool resource to generate income in an economic environment with market imperfections. We focus here on property right and credit market imperfections but assume well functioning markets for other production factors and consumption goods. This setting may describe the typical economic environment of rural areas in developing countries where households sell and buy goods on well-functioning markets but where property rights over resources are neither clearly defined nor enforced and where financial markets are often malfunctioning.

The problem of the households is described by maximizing a time separable utility function of consumption

$$\max \sum_{t=0}^{\infty} u(c_t)\beta^t. \tag{1}$$

Consumption is constrained by income from resource harvesting, investment in a harvesting technology and borrowing from imperfect credit markets. To simplify the model we assume that the household supplies labor inelastically such that resource harvesting depends only on the capital k_t and on the resource stock, x_t. Investment in harvesting capital at time t is denoted by i_t and can either be positive or negative. Negative investment levels reflect the option to sell harvesting capital. The household lives further in a small open economy and takes all prices as given. The resource income is therefore

$$y_t = ph(k_t + i_t, x_t) \tag{2}$$

where the harvest function is increasing in both arguments, concave, continuous and twice differentiable. This formulation of the harvesting function assumes first, that the investment happens before the harvest, second, that the household employs all harvesting capital and third, that the harvesting capital acts as the numeraire. The second assumption is an outcome of the optimizing behavior of the household (see Clark (1990, ch. 4.5.) for details). The resource stock grows after the harvest according to the increasing and concave function

$$x_{t+1} = f(x_t - h_t). \tag{3}$$

The other two variables that describe the state of the system are harvesting capital and the net assets of the household. The harvesting capital evolves over time according to

$$k_{t+1} = (k_t + i_t)(1 - \delta) \tag{4}$$

where $\delta \in [0, 1]$ is the capital depreciation rate. As newly invested harvesting capital is immediately employed it depreciates already after the first harvesting cycle.

Without credit market imperfections, the net assets or debts of the households develop according to

$$a_{t+1} = (1+\rho)(y_t + a_t - i_t - c_t). \tag{5}$$

where $\rho \geq 0$ is the interest rate on the financial market. In this general formulation the interest rate is the same for borrowing ($a_{t+1} < 0$) and saving ($a_{t+1} > 0$) but nothing hinges on the assumption. The interest rate is not necessarily constant but we assume that it is exogenously determined. Finally, we model property rights insecurity over the resource as the probability of expropriation θ following Bohn and Deacon (2000).

The timing of events is as follows. First, the households observes its right to harvest the resource, the asset level and the size of the resource stock. Second, it makes the investment decision, harvests the resource and consumes. Third, the resource stocks grows after the harvest and the interest payments for the next period are determined after consumption. Given the timing of events and the constraints, the household's optimization problem becomes to maximize consumption and investment in resource harvesting taking the resource dynamics, the opportunity costs of capital and the security over future resource use into account. In the tradition of dynamic programming we express the choice variables of the household, consumption and investment, as functions of the future stocks of assets, harvesting capital and resources. The Bellmann equation for the optimization problem becomes therefore

$$J(x,k,a,\theta) = \max_{k_{t+1},a_{t+1}} u\left(y_t + a_t - \frac{a_{t+1}}{1+\rho} - \frac{k_{t+1}}{1-\delta} + k_t\right) + \beta E[J(k_{t+1}, a_{t+1}, x_{t+1}, \theta)]$$

where the uncertainty over future consumption stems from the risk of expropriation. The first order conditions for capital investment and borrowing are given by

$$\begin{aligned}
&u^t_{c_t}(ph^t_{k_{t+1}} - 1) + \beta E[(1-\delta)J^{t+1}_{k_{t+1}} - J^{t+1}_{x_{t+1}} f^t_x h^t_{k_{t+1}}] = 0 \\
&- u^t_{c_t} + (1+\rho)\beta E[J^{t+1}_{a_{t+1}}] = 0.
\end{aligned}$$

In the following we use superscripts to denote the timing of functions and subscripts to denote partial derivatives e.g. $u^t_{c_t} := u'(y_t + a_t - \frac{a_{t+1}}{\rho} - \frac{k_{t+1}}{\delta} + k_t)$ etc. Using the first order conditions together with the envelope conditions for borrowing ($J_{a_t} = u^t_{c_t}$) yields the Euler equation

$$\frac{u_{c_t}}{\beta E[u_{c_{t+1}}]} = 1 + \rho. \tag{6}$$

The term on the left hand side is the inverse consumption discount factor which plays a central role in the preceding analysis. We will therefore introduce the notation $\phi_t := \frac{u_{c_t}}{\beta E[u_{c_{t+1}}]}$ for consumption discounting. Combining the first order conditions with the envelope conditions for capital ($J_{k_t} = u^t_{c_t}$) gives

$$\underbrace{(ph^t_{k_{t+1}} - 1)}_{\text{marginal profit}} + \underbrace{\frac{1}{\phi_t}}_{\text{discount factor}} \left\{ \underbrace{(1-\delta)}_{\text{future capital stock}} - \underbrace{\frac{\beta E[J_{x_{t+1}} f^t_x h^t_{k_{t+1}}]}{\beta E[u^{t+1}_{c_{t+1}}]}}_{\text{future resource stock}} \right\} = 0 \tag{7}$$

where the first term reflect the impact of one additional unit of capital on current profits from resource harvesting while the terms in the curly brackets reflect the impact of additional capital on discounted future value of the capital stocks and on the discounted future profits from resource harvesting through reduced resource stocks. Condition 7 simplifies to

$$(ph^t_{k_{t+1}} - 1) + \frac{1}{\phi_t}(1-\delta) = 0$$

under open access ($\theta = 0$). Under open access, the household takes only the returns on investment and the capital depreciation into account, neglecting its impact on the resource stock and future harvests. The first term in brackets is the instantaneous marginal profit from harvesting capital i.e. the marginal productivity of capital in resource harvesting minus the unit costs of capital. In the following, we denote the instantaneous marginal profit from harvesting capital evaluated at the optimal capital investment level, k^*, for a given level property rights security, θ, by

$$\pi^\theta := (ph_{k_{t+1}} - 1)|_{k^*,\theta}$$

From the first order conditions follows that the instantaneous profits are negative under open access as long as capital does not depreciate completely after one period. The intuition is that harvesting capital remains valuable in the next period such that the total cost of capital is the unit costs minus the discounted and depreciated future value of capital: $1 - \frac{1}{\phi}(1-\delta)$. This condition implies that the household can shift consumption from the future to the present by reducing investment levels. With complete property rights over the resource and using the envelope condition for the resource stock, $J_{x_t} = u^t_{c_t} ph^t_{x_t}$, the first order condition for capital investment reads as

$$\phi(ph^t_{k_{t+1}} - 1) + (1-\delta) - ph^{t+1}_{x_{t+1}} f^t_x h^t_{k_{t+1}} = 0.$$

The condition is deterministic as in the open access case but the household takes also its impact on future resource harvesting into account. Under secure property rights, the instantaneous profits depend not only on the capital depreciation but also on the impact of the current harvest on future resource abundance. In this case, instantaneous profit becomes not only an increasing function of capital depreciation, δ, but also increases in the fourth term, $ph^{t+1}_{x_{t+1}} f^t_x h^t_{k_{t+1}}$. This term measures the marginal impact of capital investment on future harvest via the reduction of the resource stock. This term increases in the density dependence of the harvest, $h_{x_{t+1}}$ and in the impact of resource extraction on next period resource availability (the negative of the regenerative capacity of the resource), f_x. The optimal instantaneous profit from capital investment under secure property rights can be either positive or negative. Consider the extreme cases to illustrate this statement. Under secure property rights, complete capital depreciation ($\delta = 1$), some resource dependence of the harvest ($h_{x_{t+1}} > 0$) and finite resource growth ($f_x > 0$), the instantaneous profit is positive and $\pi^{\theta=1} > 0$. The other extreme case under secure property rights with no capital depreciation ($\delta = 0$) and instantaneous regeneration of the resource ($f_x = 0$), $\pi^{\theta=1} < 0$. It depends therefore mainly on the properties of the resource stock if the household can shift more consumption to the present by increasing the harvest.

To investigate the impact of credit rationing on resource extraction we introduce an exogenous borrowing limit, α, such that

$$y_t + a_t - i_t - c_t \geq -\alpha.$$

When the credit constraint binds, the household's demand for credit exceeds α and the discount factor is larger than the market interest rate such that condition (6) no longer holds. The intuition is that an unconstrained household borrows money until the marginal utility of current consumption equals the marginal utility from repaying the loan plus its interest in future. The borrowing limit becomes binding if the consumption discounting exceeds the cost of borrowing at the point where the household borrows the maximum amount, α. A credit constraint households increases borrowing in response to a raise of the exogenous borrowing limit which increases the current consumption at the expense of future consumption. As a result of the increased borrowing, the future consumption becomes relatively more valuable and the consumption discount factor declines. If the borrowing limit increases further, the discount factor eventually reaches the market interest rate and the credit constraint becomes non-binding. The following lemma establishes this relationship formally.

Lemma 1. *An increased borrowing limit, α, reduces the discount factor of credit constraint households and has no impact on unconstrained households.*

Proof. Taking the derivative of the discount factor evaluated at $c_t = y_t + a_t - i_t + \alpha$ and $c_{t+1} =$

$y_{t+1} + i_{t+1} - \alpha\rho$ with respect to α and applying the envelope theorem yields

$$\frac{d\phi}{d\alpha} = \frac{u_{c_t c_t} \beta E[u_{c_{t+1}}] + \rho u_{c_t} \beta E[u_{c_{t+1} c_{t+1}}]}{E[\beta u_{c_{t+1}}]^2} < 0.$$

□

The credit constraint never restricts the investment in harvesting capital directly as that would imply zero consumption. Both, a decline of the interest rate and an increase of the borrowing limit affect resource use therefore only through changes in the discount rate. Based on the result of Lemma 1 we can now make the following definition to simplify the analysis.

Definition 1. *In the following we define credit market development as a reduction of consumption discounting ϕ that is either caused by a decline of the market interest rate or an increase of the borrowing limit.*

The following proposition characterize the impact of credit market development on resource exploitation in dependnence of property rights security.

Proposition 1. *There are two property rights security levels $\underline{\theta}$ and $\overline{\theta}$ with $0 < \underline{\theta} \leq \overline{\theta} \leq 1$ such that $\frac{dk^*}{d\phi} < 0$ for $\theta \leq \underline{\theta}$ and $\frac{dk^*}{d\phi} \geq 0$ for $\theta > \overline{\theta}$.*

Proof. See Appendix A. □

The proposition states that credit market developments always increases harvesting effort under insecure property rights. It also states that credit market development can lead to reduced resource extraction if $\overline{\theta} < 1$. This is the case if the impact of credit market development on the valuation of future resource stocks outweighs the impact on the harvesting costs. In addition, the two property rights security levels coincide and $\underline{\theta} = \overline{\theta}$ if the policy function is monotonous.

The intuition for this proposition is that reduced discounting increases the marginal value of future income compared to current income. Lower discount rates induce therefore more investment in harvesting if it increases future incomes relative to current incomes. This situation is more likely if households consider the future value of harvesting capital but neglect their impact on future resource stocks i.e. under insecure property rights. The proposition states further that this result is not only true for the extreme cases of private property and open access but also in a region close to the extremes.

We use this simple theoretical framework to derive two predictions for the empirical analysis: 1. Credit market development increases harvesting effort under insecure property rights and

2. The impact of credit market development on harvesting effort can be negative under secure property rights.

3 Cross-country evidence from the global fishery

In the following we test the predictions from the theoretical framework using data from 3,761 fish stocks over 55 years, covering most of the worlds commercial fisheries, combined with data on financial development and property rights security over these fish stocks. An ideal experiment for testing the impact of credit market development on resource extraction under varying levels of property rights security would assign different levels of credit market development and property rights security randomly to otherwise equal fisheries. Although property rights security is not randomly assigned to fish stocks in the real world, we use the country level implementation of the exclusive economic zones (EEZs) that changed the legal situation of more than 90 % of global fish stocks dramatically (Ebbin et al. 2005). As the EEZs did not target fish stocks specifically but rather marine resource in general, their timing resulted from an international agreement and the changes in property rights applied to all marine resources within the EEZ likewise, their implementation can be considered exogenous to the status of individual fisheries. However, the ability to implement and to enforce these rights differ between countries and fish stocks which we exploit in a differences-in-differences framework.

Also credit market development as defined in the previous section is not randomly assigned to individual fisheries but varies on the country level in response to policies such as rural credit subsidies or banking regulations, technological progress such as microfinance and mobile money or general economic development and capital accumulation. Credit market development may not only be driven by economic development but also spurs economic development. Although an impact of fisheries on credit market development seems unlikely as the fisheries sector is small in most countries compared to other economic sectors, credit market development may affect the demand for resources and the economic opportunities of the resource harvesters. Even in the ideal experiment described above it would be difficult to disentangle the effect of credit market development on the discount rate and on the economic opportunities of the resource manager (see e.g. Galor and Zeira (1993)). However, controlling for economic development, general time trends and global shocks allows us to isolate the impact of credit market development on resource extraction. We describe the estimation strategy in detail after presenting our data sources.

3.1 The status of global fisheries

The global fishery generates 100 billion USD revenues annually (Arnason et al. 2017) and employs about 57 Million people directly (FAO 2016). In addition to its importance in terms of resource rents, it is the major source of proteins for many of the global poor (FAO 2016).

Despite their importance, many of the global fisheries are depleted below the level that maximize long-run harvests (Figure 1).[4] The main driver of overfishing is over-investment in resource harvesting (Clark 2006). Resource economists often blame the lack of secure property rights over the resource as the major cause for this over-investment in harvesting capacity.

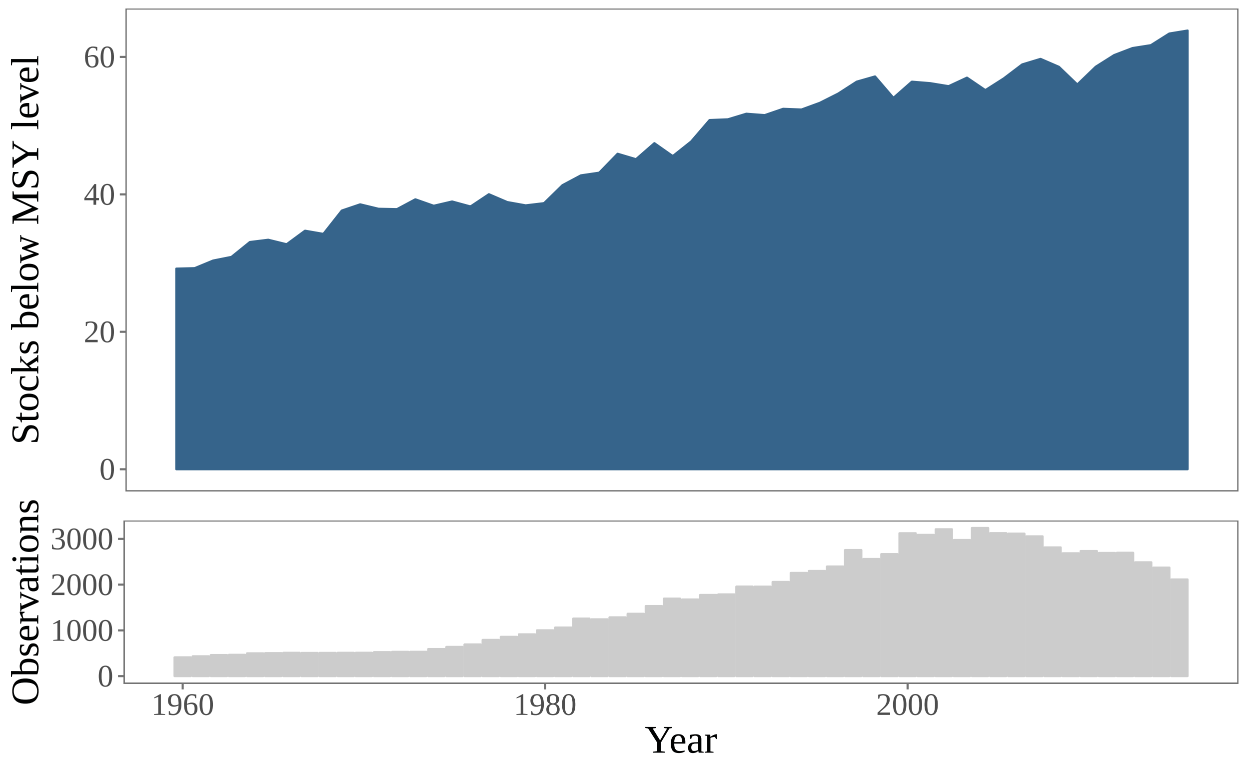

Figure 1: The figure shows the share of global fish stocks that are depleted below the level that would maximize long-run harvest in blue and the number of observations in our panel in gray. Note that our figures differ from FAO (2016) because we include only fisheries with sufficiently high data quality in the analysis. The data sources are described in the next sub-section.

The high levels of overfishing cause large economic losses because the resource stocks generate

[4]Our figures deviate from estimates by the Food and Agriculture Organization of the United Nations as we included only fish stocks with sufficiently high data quality in our analysis. Including all data would largely increase the estimated level of overfishing.

resource rents below their potential. The World Bank estimates that this overharvesting leads to annual global economic losses of 86.3 Billion USD (Arnason et al. 2017). Reducing the current exploitation rates may therefore increase resource rents and additionally benefit the global poor.

3.2 Data

In this section we describe the data used to measure resource extraction, property rights security and credit market development. Further data to control for per capita gross domestic product (GDP) in constant 2005 USD and unemployment rates are taken from the World Development Indicators (World Bank 2012) and the International Labour Organization respectively.

Resource extraction in the fishery

We measure resource extraction using a panel of fish stocks and fish catches that covers 9,318 fish stocks from 197 countries over the period from 1950 to 2015. The sample includes the vast majority of all commercially exploited fish stocks globally but small-scale fisheries in developing countries may be less well represented.

We measure resource extraction by the total annual catch of a fish stock normalized by the stock size and relative to the harvesting rate that would maximize the long-run harvest from the resource stock — the maximum sustainable yield (MSY) harvest rate. In other words we measure resource extraction relative to the MSY extraction rate. The advantage of this measure is first, that it makes resource extraction comparable across all stocks and second, that it facilitates interpretation. A resource extraction level above 100 % indicates an extraction rate that would lead to a long-term decline and finally to a collapse of the resource stock. However, temporal extraction rates above 100 % can be economically optimal for underexploited fish stocks. We therefore include the lagged estimated stock size relative to the stock size that would result from a MSY harvest (the MSY stock) as a control in our empirical specification. The data on catches and stock sizes are an updated version of the database from Costello et al. (2016) who compiled fish catches from the RAM Legacy Stock Assessment Database Ricard et al. (2012) and the Food and Agriculture Organization (FAO). The data for fish stocks sizes are either from stock assessments (all stocks from the RAM database) or simulations based on the species biology and the catch history (all stocks from the FAO database). The data and methods to estimate the stock sizes for the FAO stocks are described in Costello et al. (2016). In one robustness test, we restrict our sample to the stocks from the RAM database to exclude all simulated stock sizes. However, as stocks with formal stock assessment are concentrated in countries with high levels of property rights security and high levels of credit market development we use the complete data set for our main specification in order to increase the external validity of our results.

To further improve the quality of our data we exclude all resource stocks that were not identified to the species level such as "Tuna-like fishes" in Belize with uncertain stock estimates. Further, we exclude all stocks with less than ten years of observations since we cannot distinguish between newly exploited or newly recorded species which could potentially bias our results.

Figure 2 provides the summary statistics for the fish harvesting rate relative to the MSY harvesting rate by country over the whole time period. The figure highlights ten of the largest fishing nations from different continents and with different levels of economic development that we will also highlight as reference in the following figures. In the next subsection we show how the introduction of property rights over these resources affected the harvesting rates.

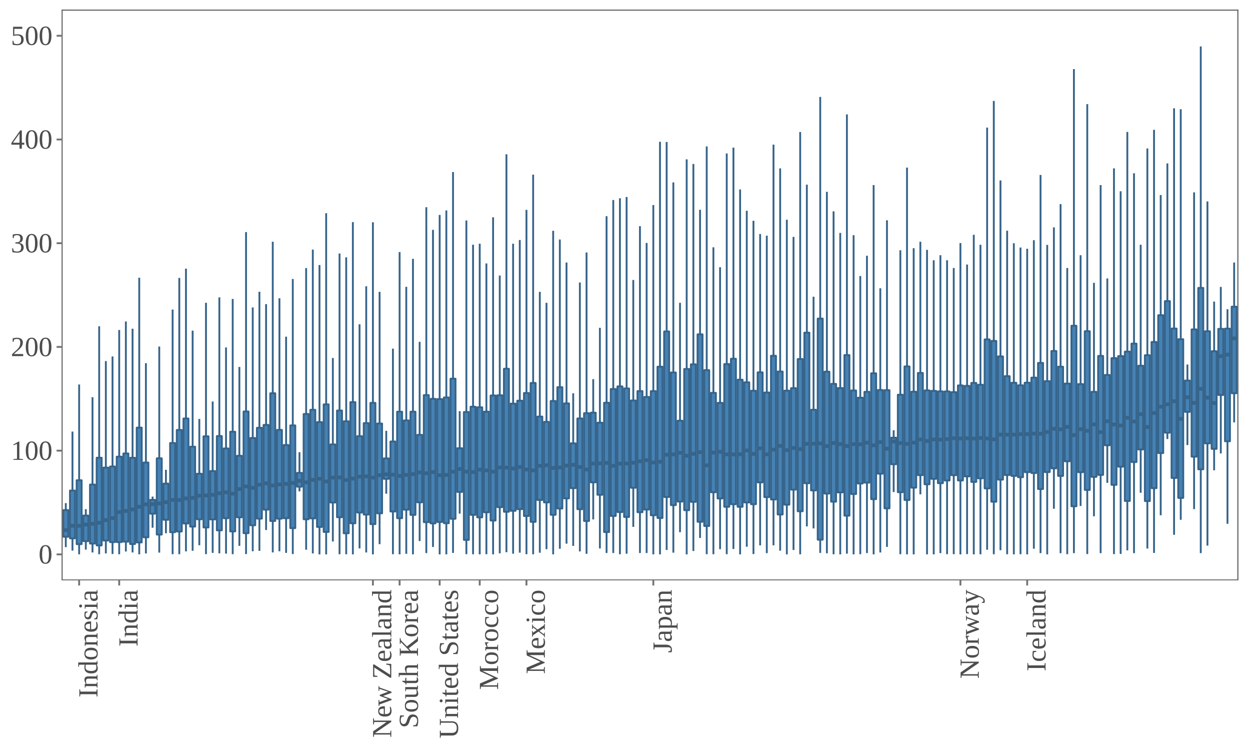

Figure 2: The boxplots show the median and the 25th and 75th percentiles of the fish harvesting rates relative to the MSY harvesting rate by country. The harvesting rates within countries vary over time and across fish stocks.

Property rights security over fish stocks

For hundreds of years the ocean fisheries where under open access with very limited possibilities for regulation. Before the United Nations Convention on the Law of the Sea (UNCLOS), countries had only legal rights over their marine resources within 12 nautical miles (nm) (22.2 km) from their coastline. This left the majority of fish stocks under open access. Fisheries regulation were further hampered by the fact that most ranges of fish stocks extended beyond the 12 nm zone such that domestic efforts to manage fisheries could be counteracted by increased harvesting effort by other fishing fleets outside the 12 nm zone. This situation changed dramatically with the UNCLOS in 1982 that allocated exclusive economic zones (EEZ) of 200 nm ($\sim$ 370.4 km) to each country and therefore established de jure property rights over marine resource in the most productive zones of the oceans.[5] The agreement included the exclusive right over the fish stocks within the EEZs but were not specifically targeted at fisheries. We therefore regard them as exogeneous to the staus of individual fisheries. However, as most EEZs extend beyond the biologically productive continental shelves they included about 90 % of the global fish stocks (Ebbin et al. 2005). Although all countries generally agree to the EEZs in general, the implementation and the enforcement of the law differed largely between countries. While some countries implemented and enforced their EEZs immediately (or even unilaterally before 1982), others are still struggling to enforce the rights over their fisheries resources (see e.g. Cabral et al. (2018)).

We use the data base from the Sea Around Us Project (Pauly and Zeller 2015) to extract the implementation year of the EEZs on national level. These dates mark the transition from open access to exclusive use rights over most fish stocks. However, the strength of those rights depends largely on the capability of a country to enforce them. To quantify strength of those rights over the fisheries resources within the EEZs we use the "Rule of Law" index from the Worldwide Governance Indicators of the World Bank (Kaufmann et al. 2011) that quantifies the quality of contract enforcement and the strength of property rights within countries. The index was assessed every two years between 1996 and 2002 and every year from then on. We interpolate the index on country level using Stineman interpolation (Moritz and Bartz-Beielstein 2017). We then normalize the index between 0 and 1 such that it matches the parameter θ in the theoretical part of the paper. In a robustness check we use the Legal System and Property Rights Index of the Fraser Institute (Fraser

[5]The areas of the EEZs often exceed the land masses of the associated country. For example, the EEZ of the US is about 2.6 times as large than the total land area of the US.

Institute 2016) which starts already in 1970 such that no extrapolation is necessary. However, the index was assessed every five year between 1970 and 2000 and we interpolate the values between the assessment dates using the same method of interpolation as for the previous index. The index of the Fraser Institute puts more weights on the intertemporal changes of property rights security within each country such that differences of the index within countries over time are often larger than the differences between countries. In contrast, the index of the World Bank rather stresses the differences in the rule of law between countries. We show time series of our property rights index for the set of countries highlighted in Figure 2 in Appendix B.

Some highly migratory species or fish stocks with large distributional ranges are caught by several nations. It is therefore impossible to establish secure property rights over the whole stocks as a share of the stock migrate between EEZs. How important the effect of sharing a fish stock on the property rights security is depends, however, on the mobility of a fish species. To capture the impact of the species' biology on the property rights security we weight the property rights security index by the number of countries harvesting a stock at the species level using $(1-\alpha) + \alpha/n$ as a weight. Here, α is the mobility parameter and and n is the number of countries catching the respective species. The index is close to unity for low values of α or small n. In a further robustness test we use these species level property rights security weights using an arbitrary value of $\alpha = 0.5$ to test the effect of species mobility on property rights security. However, since the range of species may have additional effects on the management of the resource stocks (e.g. larger stocks are more likely to be regulated in the presence of regulatory fixed costs) we use a weight of unity (or $\alpha = 0$) for our main specification.

Our property rights security measure may only reflect the government's ability to establish property rights security over the resource but not necessarily the resource harvester's property rights security over the resource stocks. However, Costello and Grainger (2018) show that the harvesters successfully lobby for policies that are in line with their individual preferences. Changes in the harvesters' discount rates may therefore directly translate into adjustments of the harvesting policy. Further, an optimal harvesting policy must take the harvesting costs into account. In that sense, our approach can be interpreted as the question of the regulator's policy takes the opportunity costs of harvesting into account.

Figure **??** depicts the mean harvest rates relative to the MSY harvest (in blue) and the property rights security (shaded areas) of ten of the world's largest fishing nations. The figure shows that while resource extraction declined after the introduction of the EEZs in countries with strong property rights security such as Iceland or Norway, the introduction of the EEZs had little impact on resource extraction of countries with weak property rights such as India or Indonesia.

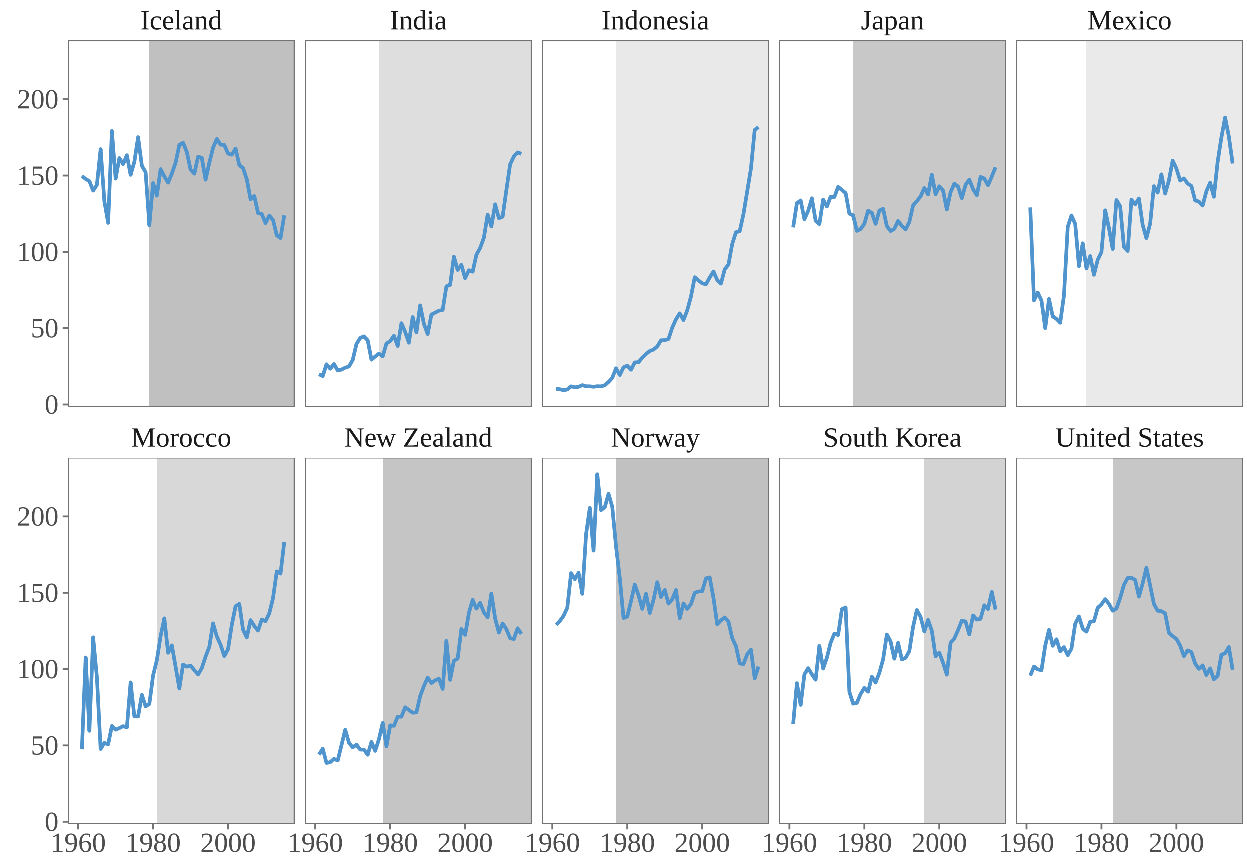

Figure 3: Mean normalized fish harvest (in blue), the introduction of national EEZs (the start of the shaded area) and the Rule of Law index (shading).

Financial development

To measure financial development we use the country average interest rates charged by banks for loans to the private sector and the volume of lending to the private sector relative to GDP. The lending interest rate measures the costs of capital and is directly related to the interest rate of the theoretical section. The volume of private credit is a common measure to describe credit market development in the financial literature (Levine et al. 2000; Beck and Levine 2004; Aghion et al. 2010, 2014; Mian et al. 2017) and is related to the credit constraints in the theoretical part of this paper.

The data on the volume private credit are from Levine et al. (2000) and Beck et al. (2010) and are updated by the World Bank. The data on lending interest rates stem from the International Financial Statistics from the International Monetary Fund (IMF). The methods used by the IMF to assess the lending interest rates differs between countries as the interest rate depends on the size and conditions of the loan. The country level differences of the assessment methods are, however, absorbed by the country level fixed effects in our empirical specification.

In a robustness check we use the nonfinancial firm debt to GDP ratio from the Bank for International Settlement's "Long series on total credit to the nonfinancial sectors" database as in Mian et al. (2017). However, these data are very similar to the data on the volume of borrowing to the private sector from Beck et al. (2010) but cover less countries.

The credit market development variables are the relevant for the private sector. However, our research question could also be interpreted as the question if governments take the opportunity cost of capital in their resource policies into account. The relevant opportunity cost of capital for the government may be poorly represented by the private sector interest rates but rather by long-term interest rates on government bonds. In a further robustness check we therefore use the interest rates on government bonds from the International Financial Statistics from the IMF.

Inflation affects interest rates directly and through financial policies. We therefore control for inflation in our regression equations using the consumer price index from the World Bank financial development indicators. Still, the recorded interest rates become unreliable in periods of hyperinflation as little differences in the assessment dates of interest rates and inflation can lead to large discrepancies. We therefore exclude all periods of hyperinflation with inflation rates of more than 30 % from our data set.

The financial time series are generally available between 1960 and 2015 but their coverage differs. After merging the data sets and excluding periods of hyperinflation we exclude all observations where either lending interest rates or credit to the private sector are missing which leaves us with 90,966 stock-year country level observations.

Figure 4 summarizes the data on credit market development. While panel A) displays the volume of lending to the private sector relative to GDP, panel B) summarizes the distribution of the lending interest rates by country.

Harvesting capital

For a tentative analysis of mechanisms we estimate the impact of credit market development on harvesting capital measured in gross tonnage of fishing fleets. Gross tonnage is a measure of

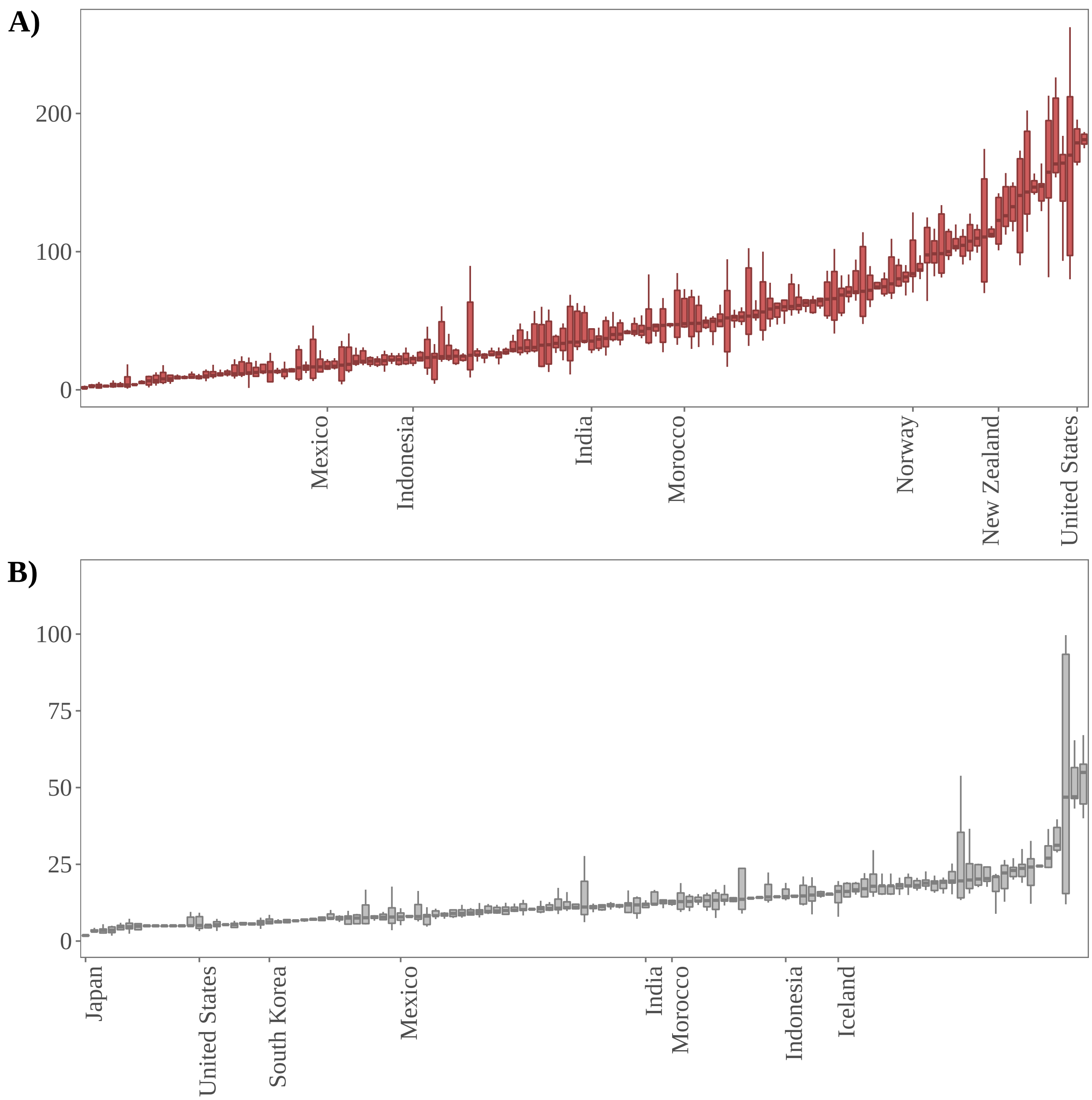

Figure 4: Panel A) shows the distribution of private credit relative to the GDP level while panel B) shows the distribution of the lending interest rates within countries. Variation of these two credit market variables within and across countries stem from credit market development and from inflation. Periods of hyperinflation (annual inflation rates exceeding 30 %) are omitted from the data. Iceland, Japan and South Korea are not highlighted in panel A) as they overlap with the United States (Iceland and Japan) and with New Zealand (South Korea). The data on lending interest rates for Norway and New Zealand are missing.

the ships' volume and is commonly used to measure the capacity of fishing fleets. The data are provided by the OECD for Argentina, Colombia, Costa Rica and Thailand in addition to all OECD countries and cover the period between 2005 and 2017.

3.3 Estimation

To estimate the effect of credit market development on resource extraction under different levels of property rights security we compare the response of the resource extraction rate to credit market development across different levels of property rights security, controlling for economic development and inflation rates and including fish stock, country and year fixed effects. This approach lead to the baseline model

$$\log(\text{extraction}_{ijt}) = \gamma_1 \text{ rights}_{ijt} + \gamma_2 \text{ credit}_{jt} + \gamma_3 \text{ rights}_{ijt} \times \text{credit}_{jt} + X_{jt} + \mu_{ij} + \nu_t + \varepsilon_{ijt} \tag{8}$$

where 'extraction$_{ijt}$' is the harvest rate of stock i in country j at time t relative to the MSY harvesting rate. The variable 'rights$_{ijt}$' indicates the property rights security over individual fish stocks. The variable 'credit$_{jt}$' is the credit market development measured by the lending interest rate in the first specification and by total lending to the private sector in the second specification. The parameter μ_{ij} are country and fish stock specific fixed effects, ν_t are year fixed effects and ε_{ijt} is an error term clustered at the country level. The vector X_{jt} contains GDP, GDP^2, the normalized fish stock in year $t-1$ as well as the inflation rate when credit market development is measured by changes in interest rates.

Resource extraction often follows a time trend driven by economic development or changes in resource stocks. Controlling for GDP in linear and squared form as well as including the lagged stock size may therefore reduce the problems that can evolve from trending variables. Other ways to address time trends in regression equations are to difference the time series or to include lagged dependent variables on the right hand side of the regression equation. These methods use different variation in the data to estimate the relation of credit market development and resource extraction. Differencing both sides of the regression equation leaves only the instantaneous changes in credit market development and changes in the resource extraction rate to estimate the relationship. Because the impact of the resource harvesters' decision to invest in new harvesting capital on resource extraction may only materialize slowly (e.g. it may take some time to build new fishing vessels), differencing may fail to capture the relationship between credit market development and resource extraction. Including a lagged dependent variable on the right hand side of the baseline regression equation is equivalent to estimating the impact of levels of credit market development on changes in the resource extraction rate. This approach also capture a slow response of resource extraction to credit market development but put large weights on fluctuations in a stochastic industry. We therefore use the baseline specification (8) with stock-country and year fixed effects as our main specification and compare the results to robustness checks with a) country level time trends, b) lagged dependent variables and c) differenced dependent and independent variables.

The impact of credit market development on resource extraction may further differ between developed and developing countries. While fishermen in developing countries are more credit constrained, their credit market situation may be less well represented by the country level credit market indicators. We therefore include regression results of our baseline specification for a sample that is restricted to OECD countries as a further robustness check.

Differences in levels of credit market development across countries are absorbed by country level fixed effects. However, the levels of credit market development affect the estimation of the interaction effects even if country level fixed effects are included in the regression specification Balli and Sørensen (2013). We therefore demean the credit market development indicators on country level. In addition, we transform all variables using inverse hyperbolic sine transformation (Burbidge et al. 1988). The interpretation of the coefficients as elasticities is similar to log transformed variables but the transformation is also defined for zeros which are common for harvest rates. The transformation reduces the skewness of the distributions but also implicitly assumes an isoelastic relationship between credit market development and the harvesting rate. This isoelastic relationship may evolve from isoelastic production functions such as Cobb-Douglas or CES but as we have not specified functional forms in our theoretical section we cannot ground this assumption directly on our theory.

3.4 Results

This section presents the results on the impact of credit market development on resource extraction. First, we present the results on the impact of interest rate changes on resource extraction. We then report the results using credit to the private sector and of interest rates of government bonds as the main explanatory variable.

Table 1 presents the results for the impact interest rate changes on the fish stock level harvesting rates. All regression specifications control for GDP, GDP^2, the resource stock in $t-1$, the inflation rate and further include stock-country level fixed effects as well as year fixed effects.

Standard errors are clustered at the country level.

The first column (Baseline) reports the result for our baseline regression specified in equation (8) with year and country-stock level fixed effects but without the interaction term of credit market development and property rights security. In this specification, we therefore estimate the mean impact of credit market development on resource extraction across all levels of property rights security. The results suggest that higher interest rates have a weakly positive impact on resource extraction (not statistically significant) while increasing property rights security reduces resource extraction. Column two (Main) presents the results of our main specification which is similar to the baseline specification but includes additionally an interaction term of interest rates and property rights security. The results of our main specification suggest that a one percent increase of the lending interest rate reduces the harvesting rate by 0.10 % under open access. In contrast, the same increase of the lending interest rate increases resource extraction under secure property rights by 0.15 %.[6] These findings are therefore in line with our theoretical prediction that credit market development (i.e. reductions of the interest rate) leads to increased resource harvesting under open access while it incentivize resource conservation under secure property rights. The results of our baseline specification show further that increased property rights security reduces the harvesting rates as the resource owner takes the future values of resources into account. Changing the property rights security from open access to secure property rights reduces resource extraction by 26 %. Including additional country level time trends has little impact on these results. The results for the main specification with additional time trends is reported in the fourth column (Trend).

To further account for the path dependencies in harvest, we include the lagged harvesting rate as an additional dependent variable in a second specification, reported in the fourth column (AR). In this specification we therefore estimates the impact of credit market development levels on changes of resource harvesting rates compared to the previous year. In other words, we estimate if high or low levels of credit market development lead to growth or decline of the harvesting rates. The interpretation of the coefficient reported in column (AR) is therefore different from the interpretation of the coefficients in the previous columns (Baseline to Trend) but the qualitative results are similar. The resource extraction rate declines when interest rates are high and property rights are insecure while the extraction rate grows under high interest rates when property rights are secure. The next column (Differenced) shows the results for a regression specification

[6]The marginal effect of the lending interest rate on the harvesting rates under secure property rights is given by the sum of the coefficient for the interest rate and the interaction term of interest rates with property rights security.

with differenced dependent and independent variables. In this specification, the coefficients can be interpreted as the impact of the growth rate of credit market development on the growth rate of resource harvesting. This specification therefore takes only immediate responses of the harvesting rate to changes of credit market development into account. Although the signs of the coefficients are generally the same as in the main specification, none of them is statistically significant. We interpret this result as indicative for slow changes in resource harvesting that rather respond to levels of credit market development than to short term credit market fluctuations. The last two column and present the results for the main specification but with the sample restricted to OECD countries (OECD) and to fish stocks from the RAM legacy database with formal stock assessments (RAM). The results are very similar to the main specification suggesting that there are no significant differences between developed and developing countries and that uncertainties over fish stock do not drive the results.

Table 1: Resource extraction and the lending interest rate

	Dependent variable: Resource extraction rate						
	Baseline	Main	Trend	AR	Differenced	OECD	RAM
Lending interest	0.05	-0.10^{**}	-0.10	-0.04^{**}	0.01	-0.14^{**}	-0.14^{***}
	(0.03)	(0.05)	(0.06)	(0.02)	(0.01)	(0.06)	(0.05)
Property rights	-0.16^{***}	-0.26^{***}	-0.24^{***}	-0.11^{***}	-0.05	-0.25^{***}	-0.31^{***}
	(0.05)	(0.06)	(0.07)	(0.02)	(0.04)	(0.08)	(0.07)
Lending interest		0.25^{***}	0.19^{**}	0.10^{***}	-0.07	0.18^{**}	0.17^{**}
× Property rights		(0.05)	(0.08)	(0.02)	(0.22)	(0.08)	(0.08)
Observations	88,243	88,243	88,243	88,243	83,488	58,427	35,983
R^2	0.56	0.56	0.57	0.77	0.04	0.56	0.77

The regression specifications are *Baseline*: as defined by equation 8 but without interaction term, *Main*: as defined by equation (8), *Trend*: as 'Main' but including additional linear country level time trends, *AR*: as 'Main' but including the lagged dependent variable as control, *Differenced*: as 'Main' but all variables differenced, *OECD*: as 'Main' but sample restricted to OECD countries, *RAM*: as 'Main' but sample restricted to fish stocks with formal stock assessment. All specifications include additionally stock-country fixed effects, year dummies, log gdp, log gdp squared, inflation rates and the fish stock size relative to its maximum MSY level in $t-1$. All variables are transformed using inverse hyperbolic sine transformation. Independent variables are additionally demeaned at the stock-country-level. Robust standard errors are clustered at the country level. Significance levels are: *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

The findings generally support our theoretical prediction that credit market developments measured in a reduction of the market interest rate leads to higher resource extraction if property rights are insecure. They suggest further that the effect of credit market development on resource extraction reverses if property rights security is strong.

Table 2 reports the results with private credit as indicator for credit market development. All specifications are otherwise as in Table **??**. However, in contrast to the previous specification where credit market development equate to a reduction of the interest rate, credit market development in the following specification implies an increase of the volume of credit to the private sector.

The estimates for the impact of property rights security on resource harvesting reported in Table 2 are very similar to the impact reported in Table 1. As in the previous version, the results of the first column (Baseline) indicate that credit market development leads overall to less resource harvesting. Our main specification reported in column two (Main) further suggests that this overall positive impact of credit market development is composed of a positive impact of credit market development on resource harvesting under open access and a negative impact of credit market development on resource harvesting under secure property rights. The results are qualitatively similar when a country level time trend (Trend) or the lagged dependent variable is included (AR) but the magnitudes of the estimates are reduced compared to our main specification. There is however no statistically significant effect of credit market development on resource extraction when only the immediate response of both variables is used to estimate the parameters (Differenced).

Lastly, restricting the sample to OECD countries (OECD) or stocks with formal stock estimates from the RAM legacy database (RAM) renders mots estimates statistically insignificant although the direction of the effects is mostly consistent with our main specification.

Overall these results support our theoretical predictions as they suggest that credit market development leads to reduced resource harvesting under secure property rights. The weak results for the impact of credit market development on resource harvesting under open access may result the economic reality of resource harvesters in economies with weak property rights regimes which may be less well described by our aggregate credit market variable.

Governments instead of individual resource harvester may set the harvesting quota under secure property rights regimes, however. Interest rates of government bonds may reflect discount rates of governments better than lending interest rates to the private sector. To test the robustness of our results with respect to government interest rates we run the same regressions as reported

Table 2: Resource extraction and the volume of credit to the private sector

Dependent variable: Resource extraction rate							
	Baseline	Main	Trend	AR	Differenced	OECD	RAM
Private credit	-0.09^{***}	0.12^{**}	0.06	0.04^{**}	-0.04	0.06	-0.05
	(0.02)	(0.05)	(0.06)	(0.02)	(0.03)	(0.12)	(0.09)
Property rights	-0.15^{***}	-0.21^{***}	-0.19^{***}	-0.09^{***}	-0.01	-0.20^{**}	-0.22^{**}
	(0.04)	(0.06)	(0.06)	(0.02)	(0.02)	(0.09)	(0.09)
Private credit		-0.41^{***}	-0.29^{**}	-0.15^{***}	-0.32	-0.27	-0.11
$\times$ Property rights		(0.12)	(0.14)	(0.04)	(0.26)	(0.20)	(0.17)
Observations	88,243	88,243	88,243	88,243	83,488	58,427	35,983
R^2	0.56	0.57	0.57	0.77	0.04	0.56	0.77

The regression specifications are *Baseline*: as defined by equation 8 but without interaction term, *Main*: as defined by equation (8), *Trend*: as 'Main' but including additional linear country level time trends, *AR*: as 'Main' but including the lagged dependent variable as control, *Differenced*: as 'Main' but all variables differenced, *OECD*: as 'Main' but sample restricted to OECD countries, *RAM*: as 'Main' but sample restricted to fish stocks with formal stock assessment. All specifications include additionally stock-country fixed effects, year dummies, log gdp, log gdp squared and the fish stock size relative to its maximum MSY level in $t-1$. All variables are transformed using inverse hyperbolic sine transformation. Independent variables are additionally demeaned at the stock-country-level. Robust standard errors are clustered at the country level. Significance levels are: *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

in table 1 but using government bonds interest rates instead of lending interest rates to the private sector. In this specification we expect on overall positive impact on higher interest rates on resource extraction as the governments have little impact on resource extraction under open access by definition. Table 3 reports the results. The sample is largely reduced compared to the sample of the previous specifications as data on government bonds exists only for fewer countries over shorter time periods.

The results are qualitatively similar to the results for lending interest rates to the private sector as credit market development indicator reported in table 1. However, the impact of interest rates on government bonds on resource extraction under open access is weak in this specification. Because we expect government bonds only to affect resource regulation, this finding is in line with our expectation.

Table 3: Resource extraction and the lending interest rate

	Dependent variable: Resource extraction rate						
	Baseline	Main	Trend	AR	Differenced	OECD	RAM
Interest bonds	0.15^{**}	-0.05	0.02	-0.05	-0.02	0.02	0.06
	(0.06)	(0.10)	(0.10)	(0.05)	(0.04)	(0.15)	(0.19)
Property rights	-0.02	-0.18^{**}	-0.08	-0.10^{***}	-0.00	-0.12^{*}	-0.14
	(0.07)	(0.07)	(0.06)	(0.04)	(0.03)	(0.07)	(0.08)
Interest bonds		0.28^{**}	0.07	0.13^{**}	0.32	0.15	0.03
× Property rights		(0.14)	(0.15)	(0.06)	(0.23)	(0.22)	(0.27)
Num. obs.	36,968	36,968	36,968	36,968	34,974	31,118	16,741
R^2 (full model)	0.59	0.59	0.60	0.79	0.03	0.59	0.75

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

The regression specifications are *Baseline*: as defined by equation 8 but without interaction term, *Main*: as defined by equation (8), *Trend*: as 'Main' but including additional linear country level time trends, *AR*: as 'Main' but including the lagged dependent variable as control, *Differenced*: as 'Main' but all variables differenced, *OECD*: as 'Main' but sample restricted to OECD countries, *RAM*: as 'Main' but sample restricted to fish stocks with formal stock assessment. All specifications include additionally stock-country fixed effects, year dummies, log gdp, log gdp squared, inflation rates and the fish stock size relative to its maximum MSY level in $t-1$. All variables are transformed using inverse hyperbolic sine transformation. Independent variables are additionally demeaned at the stock-country-level. Robust standard errors are clustered at the country level. Significance levels are: *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Overall the results support our theoretical predictions that credit market development leads to increased resource extraction under open access while it reduces resource extraction when property rights are secure. This general conclusion is robust with respect to other specifications of property rights security reported in Appendix.

Generally, the effect of credit market development on resource extraction becomes larger and more statistically significant if the property rights security index is weighted inversely by the number of countries catching the same fish species. These results suggest that it is more difficult to establish secure property rights over shared fish stocks. The results are reported in Appendix C.1. The reverse is true if property rights security is measured by the index of the Fraser institute. This is especially true for the direct impact of property rights security on the resource extraction rate which suggests that the index of the Fraser Institute captures the property rights security over resources less well than the Rule of Law index by the World Bank. The results using the index of the Fraser Institute to measure property rights security is reported in Appendix C.2.

One channel through which credit markets affect harvesting rates is through their impact on investment in harvesting capital. In the following we present suggestive evidence on the impact of credit market development on harvesting capital.

Next, we present suggestive evidence on the impact of credit market development on investment in harvesting capital. We only estimate the baseline equation with harvesting capital in gross tonnage as the dependent variable and credit market development as the independent variable since our data on harvesting capital covers a short time period and contains countries with high levels or property rights security. We use the lending interest rates to the private sector and the volume of credit to the private sector to measure credit market development as they capture the incentives of the capital owners. Including country level and year fixed effects and clustering our standard errors at the country level our results show that an increase of the interest rate by one percent reduces harvesting capital by 0.4 ($\pm$ 0.3) percent. Likewise, an increase of credit to the private sector by one percent increases harvesting capital by 0.5 ($\pm$ 0.5) percent. Although these estimates are not statistically significant at the 10 % level they can be interpreted as suggestive evidence for the impact of credit market on harvesting capital.

3.5 Simulations

In the following we illustrate the impact of credit market development and property rights security on resource extraction. The parameter estimates for the simulations are taken from Table 1.[7] The blue boxplots of Figure 5 show the actual within country distribution of resource extraction rates in the year 2012. The red boxplots show the distribution of resource extraction rates after shocks in credit market development and property rights security. The red boxplots of panel A) depict the distribution of resource extraction rates after a global drop of interest rates to 3.25 % (the US level in 2012) everything else kept equal. Panel B) in contrast shows the impact of an increase of

[7] To compute resource extraction rates under different levels of credit market development and property rights security we use the following approach:

$$\text{extraction}_{ijs} = \sinh\left[\text{ihs}(\text{extraction}_{ijt}) + \gamma_1(\text{rights}_{ijs} - \text{rights}_{ijt}) + \gamma_2(\text{credit}_{ijs} - \text{credit}_{ijt}) + \gamma_3(\text{rights}_{ijs}\text{credit}_{ijs} - \text{rights}_{ijt}\text{credit}_{ijt})\right]$$

where the variable and parameter definitions are as in equation (8), the parameter values for γ_1 to γ_3 are from Table 1, s denotes the value of a variable after a shock, *ihs* is the inverse hyperbolic sine transformation and *sinh* is the hyperbolic sine function.

property rights security levels to unity across all countries but under actual levels of credit market development in red. Lastly, Panel C) shows the impact a simultaneous change of property rights security to unity and a reduction of interest rates to 3.25 % on the within and across country distribution of resource extraction rates in red. The same countries as in Section 3.2 are highlighted. Panel A) illustrates that credit market development has little impact on overall resource extraction rates under current levels of property rights security. The main reason for the small impact of credit market development is that most countries have intermediate levels of property rights security such that the impact of credit market development on the value of future resource stocks and the impact on capital costs cancel out. In other words, the impact of credit market development on the capacity of the harvesting fleet and on more strict resource regulation cancel out. Panel B) shows that increasing property rights security to its maximum level has a much larger impact on resource extraction rates than credit market development. However, improving credit markets and property rights security simultaneously as shown in panel C) has the largest impact on resource extraction because increasing property rights security amplifies the positive impact of credit market development on resource conservation.

To quantify these changes we can compare the actual global average harvesting rate to the harvesting rates that would result from changes in property rights security and credit market development. The overall mean resource extraction rates in 2012 was 99 % of the maximum sustainable yield level. Reducing interest rates across the globe to 3.25 % does not change this figure. In contrast, increasing property rights security to its maximum and increasing property rights security and levels of credit market development simultaneously reduces mean resource extraction rates to 82 % and to 77 % respectively. The figures do not imply that global fisheries are underfished. In 2012, about 41 % of the global fisheries were fished beyond the maximum sustainable yield level. A reduction of the interest rate to 3.25 %, an increase of property rights security to one and a simultaneous change of both variables would reduce the share of fisheries that are harvested beyond the maximum sustainable yield level to 41%, 32 % and 29 % respectively. While some fisheries are overfished, other fisheries are harvested below the maximum sustainable yield level. These relatively low extraction rates may be a consequence of transitional dynamics or a result of high harvesting costs and low resource prices. Changes in harvesting rates do therefor not directly translate into economic gains or losses. However, recent figures by the World Bank for the year 2012 suggest that global overfishing led to global economic losses of 86.3 billion (Arnason et al. 2017).

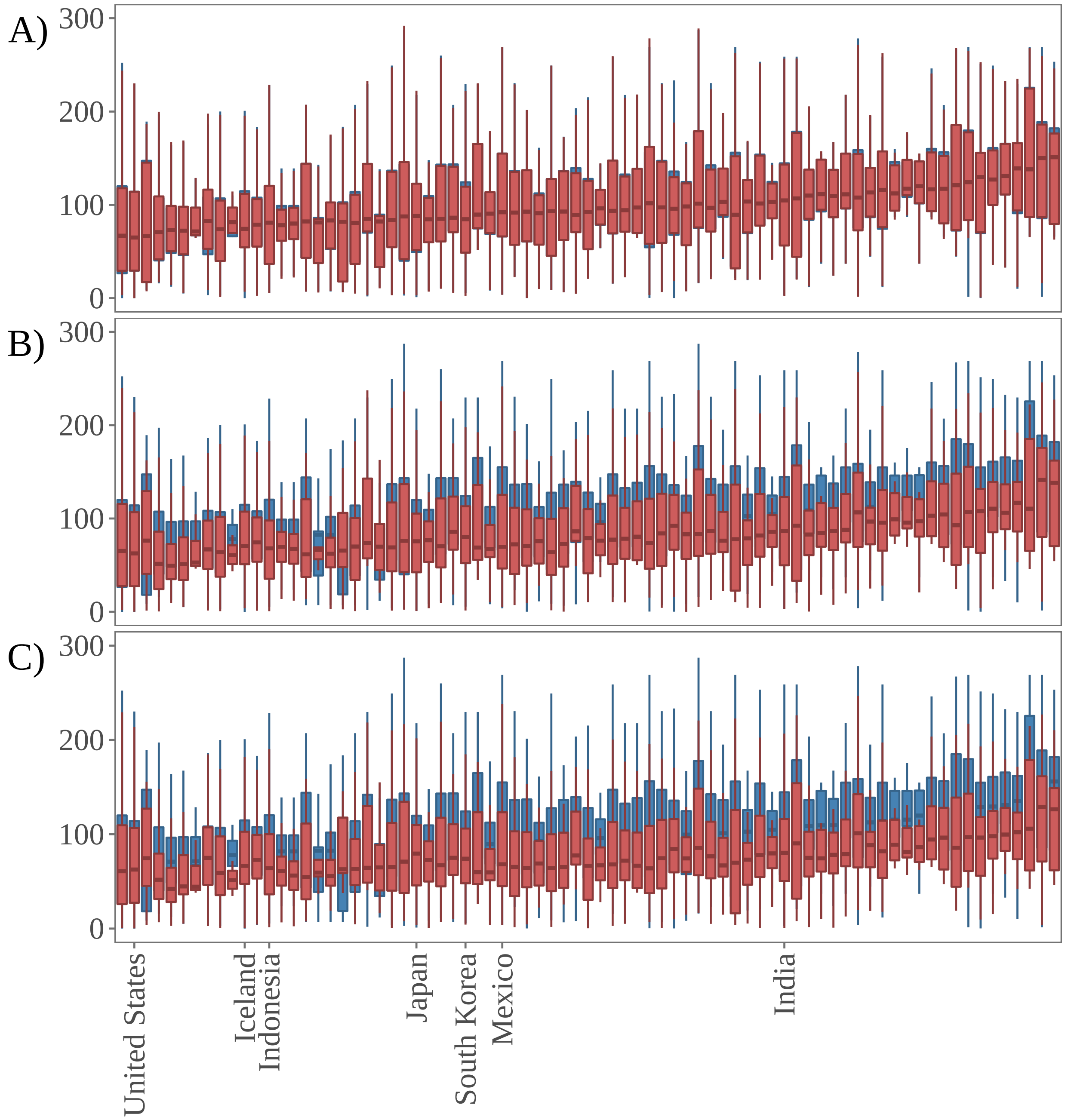

Figure 5: The figure shows the current within country distribution of resource extraction in 2012 in blue and in red A) the distribution of resource extraction rates after a global conversion of interest rates to US levels (3.25 %) B) a global increase of property rights security to unity and C) a simultaneous change of interest rates to 3.25 % and property rights security to unity.

4 Discussion and Conclusions

Discounting plays an important role for determining optimal resource use and environmental conservation. Despite the prominent role of discounting for resource management and the rapid expansion of financial markets around the world, to our knowledge, this is the first study that estimates the impact of credit market development on resource extraction. To identify the impact of credit market development on resource extraction we make use of a new data set on fish catches and fish stocks sizes combined with data on property rights security, financial development and economic performance covering the majority of all commercial fisheries in the world. These novel data allow us to isolate the impact of credit market development and property rights on resource extraction.

Our results show that credit market development and property rights security affect resource extraction. While a reduction of the interest rate by one percent increases resource extraction by 0.1 % under open access but reduces resource extraction by 0.15 % under secure property rights security. We find similar effects for the volume of credit to the private sector as credit market indicator. The parameter estimates of our main specification indicate that an increase of credit to the private sector by one percent increases resource extraction under open access by 0.12 % but decreases resource extraction under secure property rights by 0.29 %. The results show further that increasing property rights security from open access to complete property rights security reduces resource extraction rates by 21 to 26 %.

Our simulation results show, however, that the impact of credit market development on resource extraction is small under current levels of property rights security. The reason for these small impact of credit market development on resource extraction comes from the fact that the impact of credit markets on investment in harvesting capital and the impact on resource regulation cancel out under current levels of property rights security. However, the results show further that credit market development can largely contribute to resource conservation under secure property rights over resources.

The economic implications of these results are far reaching. Arnason et al. (2017) estimate that the losses due to overfishing in 2012 were 86 Billion USD. Our results show that improving property rights security and promoting credit market development has the potential to reduce overfishing by about one third. To quantify the exact economic benefits of these reductions of overfishing are beyond the scope of this paper. However, our result that strengthening property rights security reverses the negative impact of credit market development on resource extraction shows that economic development can contribute to resource conservation if property rights over resources are clearly defined and enforced.

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A Proof of Proposition 1

Proof. The proof follows in two steps. The first step show the impact of ϕ on the extremes, $\theta = 0$ and $\theta = 1$. The second part establishes continuity of k^*.

1. Implicitly differentiating (7) with respect to ϕ for $\theta = 0$ and using the relationship $(ph_{k_{t+1}} - 1) = -(1-\delta)/\phi$ yields

$$\frac{dk^*}{d\phi} = \frac{J_{k\rho}}{-J_{kk}} = \frac{(ph^t_{k_{t+1}} - 1)}{-J_{kk}} = \frac{1-\delta}{\phi J_{kk}} < 0.$$

   Note that the value function is concave (see Acemoglu (2009, p. 189) for a proof) such that $J_{kk} < 0$. Repeating the exercise with $\theta = 1$ yields

$$\frac{dk^*}{d\phi} = -\frac{J_{k\phi}}{J_{kk}} = \frac{(ph^t_{k_{t+1}} - 1)}{-J_{kk}} = \frac{1-\delta - ph^{t+1}_{x_{t+1}} f^t_x h^t_{k_{t+1}}}{\phi J_{kk}} \lesseqqgtr 0.$$

   To see the ambiguity consider the cases of no capital depreciation, $\delta = 0$, and no stock dependence of the harvest $h^{t+1}_{x_{t+1}} = 0$. Next consider complete capital depreciation, $\delta = 1$, and stock dependent harvest, $h^{t+1}_{x_{t+1}} > 0$.

2. Continuity of the policy function, k^*, follows from the continuity of the objective function (see Acemoglu (2009, p. 190) for a proof).

Combing 1 & 2, there must be a $\underline{\theta} > 0$ such that $\frac{dk^*}{d\phi} < 0$ for $\theta \leq \underline{\theta}$ and a $\overline{\theta} \leq 1$ such that $\frac{dk^*}{d\phi} > 0$ for $\theta > \overline{\theta}$. For $\delta + ph^{t+1}_{x_{t+1}} f^t_x h^t_{k_{t+1}} \leq 1$ either $\overline{\theta} = 1$ or $\overline{\theta} = \underline{\theta} = 1$. In addition, if the policy function is monotoneous then $\overline{\theta} = \underline{\theta}$ for all $\overline{\theta}, \underline{\theta} \in (0, 1]$. □

B Data

The following figures show the property rights security index for fish stocks using the Rule of Law Index of the World Bank and the Legal System and Property Rights Security index of the Fraser Institute for the same set of countries highlighted in Section 3.2.

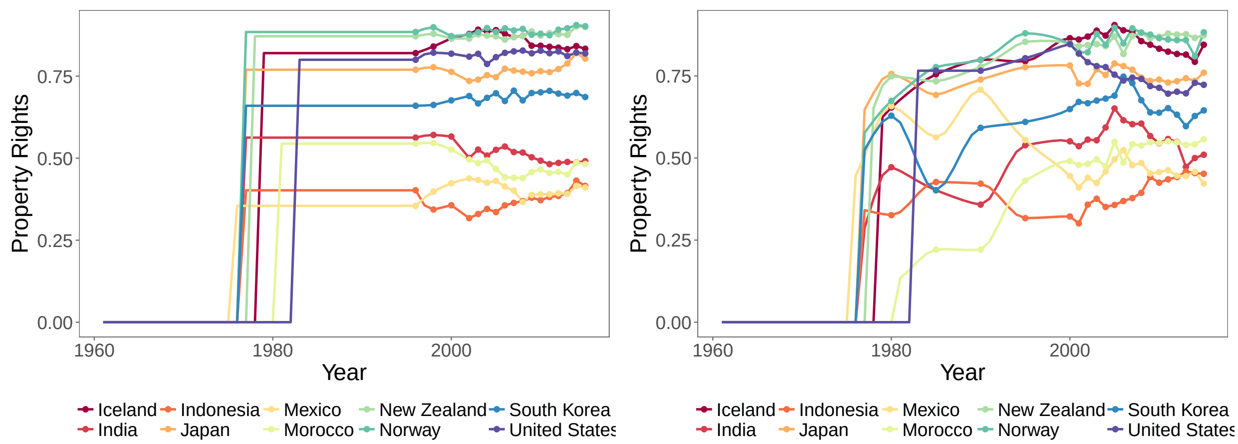

Figure 6: Property rights security index using the World Bank rule of law index with linear extrapolation.

C Robustness

C.1 Robustness: Accounting for Species Mobility in Property Rights Security

In the following, we present the results using the Rule of Law Index by the World Bank as our property rights security indicator weighted by $(1 + 0.5/n_i)$ at the species level (see Section 3.2). The number of countries catching species i is denoted by n_i. All specifications are as in our results section 3.4. Table 4 summarizes the results using the lending interest rate to the private sector as credit market variable, Table 5 uses the volume of credit to the private sector as credit market variable and Table 6 uses the interest rate on government bonds as credit market variable.

Table 4: Resource extraction and the lending interest rate

	Dependent variable: Resource extraction rate						
	Baseline	Main	Trend	AR	Differenced	OECD	RAM
Lending interest	0.05	-0.16^{***}	-0.17^{***}	-0.06^{***}	0.01	-0.19^{***}	-0.17^{***}
	(0.03)	(0.04)	(0.06)	(0.02)	(0.01)	(0.06)	(0.05)
Property rights	-0.27^{***}	-0.42^{***}	-0.40^{***}	-0.17^{***}	-0.12^{**}	-0.38^{***}	-0.28^{**}
	(0.10)	(0.10)	(0.13)	(0.04)	(0.05)	(0.14)	(0.12)
Lending interest		0.59^{***}	0.54^{***}	0.22^{***}	-0.25	0.49^{***}	0.40^{***}
$\times$ Property rights		(0.09)	(0.13)	(0.04)	(0.27)	(0.13)	(0.09)
Observations	88,210	88,210	88,210	88,210	83,454	58,394	35,950
R^2	0.56	0.57	0.57	0.77	0.04	0.56	0.77

The regression specifications are *Baseline*: as defined by equation 8 but without interaction term, *Main*: as defined by equation (8), *Trend*: as 'Main' but including additional linear country level time trends, *AR*: as 'Main' but including the lagged dependent variable as control, *Differenced*: as 'Main' but all variables differenced, *OECD*: as 'Main' but sample restricted to OECD countries, *RAM*: as 'Main' but sample restricted to fish stocks with formal stock assessment. All specifications include additionally stock-country fixed effects, year dummies, log gdp, log gdp squared, inflation rates and the fish stock size relative to its maximum MSY level in $t-1$. All variables are transformed using inverse hyperbolic sine transformation. Independent variables are additionally demeaned at the stock-country-level. Robust standard errors are clustered at the country level. Significance levels are: *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table 5: Resource extraction and the volume of credit to the private sector

	Dependent variable: Resource extraction rate						
	Baseline	Main	Trend	AR	Differenced	OECD	RAM
Private credit	-0.09^{***}	0.16^{***}	0.12^{**}	0.05^{***}	-0.04	0.15	0.04
	(0.02)	(0.06)	(0.06)	(0.02)	(0.03)	(0.11)	(0.08)
Property rights	-0.27^{***}	-0.30^{***}	-0.27^{***}	-0.13^{***}	-0.04	-0.27^{**}	-0.22^{*}
	(0.09)	(0.08)	(0.09)	(0.03)	(0.03)	(0.11)	(0.11)
Private credit		-0.82^{***}	-0.70^{***}	-0.30^{***}	-0.53^{*}	-0.69^{**}	-0.48
× Property rights		(0.21)	(0.22)	(0.08)	(0.28)	(0.30)	(0.30)
Observations	88,210	88,210	88,210	88,210	83,454	58,394	35,950
R^2	0.56	0.57	0.57	0.77	0.04	0.56	0.77

The regression specifications are *Baseline*: as defined by equation 8 but without interaction term, *Main*: as defined by equation (8), *Trend*: as 'Main' but including additional linear country level time trends, *AR*: as 'Main' but including the lagged dependent variable as control, *Differenced*: as 'Main' but all variables differenced, *OECD*: as 'Main' but sample restricted to OECD countries, *RAM*: as 'Main' but sample restricted to fish stocks with formal stock assessment. All specifications include additionally stock-country fixed effects, year dummies, log gdp, log gdp squared and the fish stock size relative to its maximum MSY level in $t-1$. All variables are transformed using inverse hyperbolic sine transformation. Independent variables are additionally demeaned at the stock-country-level. Robust standard errors are clustered at the country level. Significance levels are: *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table 6: Resource extraction and the interest rates on government bonds

	Dependent variable: Resource extraction rate						
	Baseline	Main	Trend	AR	Differenced	OECD	RAM
Interest bonds	0.16^{**}	-0.04	-0.08	-0.02	-0.02	-0.05	0.01
	(0.06)	(0.08)	(0.07)	(0.03)	(0.04)	(0.10)	(0.08)
Property rights	0.02	-0.12	-0.12	-0.07	-0.04	-0.11	0.07
	(0.11)	(0.12)	(0.13)	(0.04)	(0.04)	(0.16)	(0.16)
Interest bonds		0.42^{***}	0.34^{***}	0.15^{***}	0.29	0.38^{***}	0.22^{***}
× Property rights		(0.08)	(0.07)	(0.05)	(0.28)	(0.08)	(0.08)
Observations	36,935	36,935	36,935	36,935	34,940	31,085	16,708
R^2	0.59	0.59	0.60	0.79	0.03	0.59	0.75

The regression specifications are *Baseline*: as defined by equation 8 but without interaction term, *Main*: as defined by equation (8), *Trend*: as 'Main' but including additional linear country level time trends, *AR*: as 'Main' but including the lagged dependent variable as control, *Differenced*: as 'Main' but all variables differenced, *OECD*: as 'Main' but sample restricted to OECD countries, *RAM*: as 'Main' but sample restricted to fish stocks with formal stock assessment. All specifications include additionally stock-country fixed effects, year dummies, log gdp, log

C.2 Robustness: Legal System and Property Rights Security index of the Fraser Institute

In the following, we present the results using the index of 'Legal System and Property Rights Security' of the Fraser Institute (see Section 3.2) as our property rights security indicator for the period after the introduction of EEZs. All specifications are as in our results section 3.4. Table 7 summarizes the results using the lending interest rate to the private sector as credit market variable, Table 8 uses the volume of credit to the private sector as credit market variable and Table 9 uses the interest rate on government bonds as credit market variable.

Table 7: Resource extraction and the lending interest rate

	Dependent variable: Resource extraction rate						
	Baseline	Main	Trend	AR	Differenced	OECD	RAM
Lending interest	0.05	−0.08	−0.08	−0.03	0.01	−0.11	−0.10
	(0.03)	(0.06)	(0.07)	(0.02)	(0.01)	(0.07)	(0.07)
Property rights	−0.09	−0.19**	−0.20**	−0.08***	−0.07	−0.23**	−0.20**
	(0.05)	(0.08)	(0.10)	(0.03)	(0.05)	(0.11)	(0.10)
Lending interest		0.23***	0.18*	0.09***	−0.19	0.15	0.11
× Property rights		(0.08)	(0.10)	(0.03)	(0.26)	(0.11)	(0.13)
Observations	86,044	86,044	86,044	86,044	81,448	58,427	35,105
R^2	0.56	0.56	0.57	0.76	0.04	0.56	0.76

The regression specifications are *Baseline*: as defined by equation 8 but without interaction term, *Main*: as defined by equation (8), *Trend*: as 'Main' but including additional linear country level time trends, *AR*: as 'Main' but including the lagged dependent variable as control, *Differenced*: as 'Main' but all variables differenced, *OECD*: as 'Main' but sample restricted to OECD countries, *RAM*: as 'Main' but sample restricted to fish stocks with formal stock assessment. All specifications include additionally stock-country fixed effects, year dummies, log gdp, log gdp squared, inflation rates and the fish stock size relative to its maximum MSY level in $t-1$. All variables are transformed using inverse hyperbolic sine transformation. Independent variables are additionally demeaned at the stock-country-level. Robust standard errors are clustered at the country level. Significance levels are: *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table 8: Resource extraction and the volume of credit to the private sector

	Dependent variable: Resource extraction rate						
	Baseline	Main	Trend	AR	Differenced	OECD	RAM
Private credit	-0.09^{***}	0.09^{*}	0.02	0.03^{*}	-0.05^{*}	0.03	-0.13
	(0.02)	(0.05)	(0.06)	(0.02)	(0.03)	(0.10)	(0.09)
Property rights	-0.07	-0.13^{**}	-0.13^{**}	-0.05^{***}	-0.03	-0.16^{**}	-0.10
	(0.05)	(0.05)	(0.06)	(0.02)	(0.03)	(0.08)	(0.08)
Private credit		-0.35^{***}	-0.24^{*}	-0.14^{***}	0.07	-0.24	0.01
× Property rights		(0.10)	(0.13)	(0.03)	(0.34)	(0.19)	(0.15)
Observations	86,044	86,044	86,044	86,044	81,448	58,427	35,105
R^2	0.56	0.56	0.57	0.76	0.04	0.56	0.77

The regression specifications are *Baseline*: as defined by equation 8 but without interaction term, *Main*: as defined by equation (8), *Trend*: as 'Main' but including additional linear country level time trends, *AR*: as 'Main' but including the lagged dependent variable as control, *Differenced*: as 'Main' but all variables differenced, *OECD*: as 'Main' but sample restricted to OECD countries, *RAM*: as 'Main' but sample restricted to fish stocks with formal stock assessment. All specifications include additionally stock-country fixed effects, year dummies, log gdp, log gdp squared and the fish stock size relative to its maximum MSY level in $t-1$. All variables are transformed using inverse hyperbolic sine transformation. Independent variables are additionally demeaned at the stock-country-level. Robust standard errors are clustered at the country level. Significance levels are: *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table 9: Resource extraction and interest rates on government bonds

	Dependent variable: Resource extraction rate						
	Baseline	Main	Trend	AR	Differenced	OECD	RAM
Interest bonds	0.16***	0.05	0.11	−0.01	−0.02	0.12	0.33
	(0.06)	(0.14)	(0.14)	(0.05)	(0.04)	(0.20)	(0.29)
Property rights	0.09*	−0.02	0.08	−0.04	−0.00	0.03	0.28
	(0.05)	(0.12)	(0.12)	(0.04)	(0.04)	(0.12)	(0.24)
Interest bonds		0.18	−0.05	0.10	0.32	0.04	−0.34
× Property rights		(0.22)	(0.23)	(0.08)	(0.22)	(0.31)	(0.44)
Observations	36,874	36,874	36,874	36,874	34,908	31,118	16,685
R^2	0.59	0.59	0.60	0.79	0.03	0.59	0.75

The regression specifications are *Baseline*: as defined by equation 8 but without interaction term, *Main*: as defined by equation (8), *Trend*: as 'Main' but including additional linear country level time trends, *AR*: as 'Main' but including the lagged dependent variable as control, *Differenced*: as 'Main' but all variables differenced, *OECD*: as 'Main' but sample restricted to OECD countries, *RAM*: as 'Main' but sample restricted to fish stocks with formal stock assessment. All specifications include additionally stock-country fixed effects, year dummies, log gdp, log gdp squared, inflation rates and the fish stock size relative to its maximum MSY level in $t-1$. All variables are transformed using inverse hyperbolic sine transformation. Independent variables are additionally demeaned at the stock-country-level. Robust standard errors are clustered at the country level. Significance levels are: *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.