Rights to the forest, REDD+ and Elections: Mining in Guyana

1. Introduction

Property rights are a crucial aspect of natural resource management. They define the incentives to use, manage and preserve natural resources. How property rights are taken out, held and given up are important components of how such resources are exploited and as such a wide literature has emerged focusing on the impact of insecure property rights upon environmental outcomes such as deforestation (Angelsen, 1999; Araujo, Bonjean, Combes, Combes Motel, & Reis, 2009; Bohn & Deacon, 2000; Deacon, 1999; Mendelsohn, 1994). Yet to date there is little literature highlighting the factors behind how property rights to resources in more secure regimes are held and given up.

Adopting Daniel Bromley's definition of property rights[1] highlights the importance of the enforcement of the rights and duties commensurate with property in determining the incentive to hold property rights, and then in turn invest in various factors of production (North 1981). These incentives are just as crucial in developing countries.[2] Understanding the factors laying behind the holding of property rights to natural resources can help to create understanding regarding the investment in, and growth of natural resource extractive industries.

The risk of expropriation of natural resource property rights has been a common phenomenon in a number of countries in recent decades and has sprouted a literature discussing both the causes and consequences (Hogan & Sturzenegger, 2010; Kobrin, 1984; Leon, 2009; J. Thomas & Worrall, 1994).[3] Expropriation may be the consequence of long-term economic policy, or following short-term events, such as elections or the introduction of new environmental policy. These events may change the pattern of behaviour of property rights holders as they create uncertainty over the potential benefit streams of rights, and indeed the validity of the rights themselves.

Although there is a body of literature relating to the role that property rights have played in the growth of industries such as agriculture in forested environments, other drivers of deforestation such as artisanal and small-scale mining (ASM) have not yet been studied in this context - indeed the study of the holding of property rights for mining generally, and small-scale mining in particular, is

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[1] Bromley, (1991) defines property as *'Property is not an object but rather is a social relation that defines the property holder with respect to something of value (the benefit stream) against all others. Property is a triadic social relation involving benefit streams, rights holders, and duty bearers.'* pp. 2

[2] As illustrated by Hernando de Soto's seminal work on the economic importance of property rights in Peru (De Soto, 1989) and Tim Besley's work in Ghana (Besley 1995).

[3] Hogan and Sturzenegger (2010) provide an elegant categorisation of these different types of expropriation. They define expropriation as either direct, such as the Bolivian takeover of Standard Oil assets in 1937 (Geiger, 1989), or indirect (or creeping), relating to governments assuming a larger share of projects, increasing royalties or tax rates, or changing environmental regulations.

under-researched. Yet small-scale mining has emerged in recent years as an important economic activity, an important provider of livelihoods and also a major source of environmental damage including water pollution and deforestation (Gardner, 2012, Megevand et al., 2013). The little modelling that exists on the decision-making processes of mining operators has focused on large-scale operators (Slade, 2001, Tole & Koop, 2011). The illegal and/or semi-formal nature of small-scale mining operations in many countries has hindered research, partly due to a lack of quantitative data on the scale, scope and evolution of the phenomenon. There is however a literature examining the drivers of small-scale mining, focusing primarily on the reasons behind its illegality (Aryee, Ntibery, & Atorkui, 2003, Hilson & Potter, 2003, Jønsson & Fold, 2011)**.** In recent years a growing recognition of the importance of small-scale mining as both a livelihood activity, and a cause of environmental damage, coupled with improved access to data has led to an increase in research in the area. The importance of small-scale mining as a driver of deforestation is highlighted in the seminal paper by Asner, et al, (2013). Other literature has examined the growth and development of small-scale mining across the Amazon (Cremers, Kolen, & de Theije, 2013).

A literature has also emerged examining a number of questions regarding the interaction between resource extraction and political institutions. Papers have examined questions such as whether democracy still yields the expected economic benefits in resource-rich countries (Collier & Hoeffler, 2005, 2009); the importance of political institutions in determining the social and economic outcomes of resource booms (Andersen & Aslaksen, 2008; Robinson, Torvik, & Verdier, 2006); the impact of large natural resource sectors upon the evolution of democratic institutions (Jensen & Wantchekon, 2004); and the interactions between resource extraction and types of political system on the tendency of regions to fall into civil war (Neudorfer & Theuerkauf, 2014). This literature has generally approached the issue from the perspective of the impact of the level of resource-extraction on political institutions, or the overall societal outcomes occurring from a combination of resource extraction and political institutions. A notable exception is work from Ghana examining the influence of small-scale mining upon local politics (Teschner, 2012). Where a major gap exists is the reverse of these questions: how political institutions and events impact on the resource-extraction sector. It is this gap that this paper contributes through examining how political events have shaped the evolution of mining property rights in Guyana.

Guyana provides an interesting case study to examine the evolution of mining property rights. Its current deforestation pattern is not dominated by agriculture, but instead small-scale gold mining (Guyana Forestry Commission & Indufor, 2013). Its economy is heavily dependent on this mining activity, but at the same time it has rapidly moved to be one of the world leading implementers of

Reducing Emissions from Deforestation and forest Degradation (REDD+). A national-level REDD+ framework is being constructed, built upon a Memorandum of Understanding (MOU) with Norway that provides up to US$250 million in finance linked to Guyana's performance in keeping deforestation rates low. A related Low Carbon Development Strategy (LCDS) serves as the channel for the use of this finance. Guyana is a democratic country, but its recent elections have been fraught with both controversy and violence, leading to unstable policy environments in the run-up to, and the aftermath of election events. It provides an example of a country where the risk of expropriation, and policy and investment uncertainty, has been common in its recent history, and therefore allows a study of how this risk has affected the holding of forest-related property rights.

In Guyana the majority of the literature produced relating to the small-scale mining industry has focused on broad strategic questions regarding the overall performance of the sector and its relation to national policy such as the LCDS (Lowe 2006, Thomas 2009, Singh et al., 2013). The broad characteristics of Guyana's mining industry are highlighted by Clifford, (2011), highlighting the similarities and differences with comparable industries across the world. Regionally there have been just two quantitative assessments of mining activity, a small-scale time series analysis of the mining behaviour of the Ndyuka people of Suriname (Heemskerk 2001) and a quantitative analysis of mining in the Guiana Shield as a whole (Hammond, Gond, de Thoisy, Forget, & DeDijn, 2007).

This paper extends the literature relating to expropriation and property rights, the impact of REDD+ policy on property rights to the forest, the driving forces behind small-scale mining and the interactions between political institutions and resource extraction. It uses a unique data set of 17 years of mining claim data for Guyana to examine the evolution of mining property rights across the country, focusing on questions relating to how elections and the introduction of REDD+ has affected how mining claims have been taken out, held and given up.

An econometric model is estimated to describe the factors affecting the number of mining property rights taken out or given up in each year. It focuses on how election cycles, and the introduction of REDD+ has affected the incentives to hold these rights. The model finds that elections seem to have a significant, and negative, effect on the number of claims being taken out, not in the year of the elections themselves, but in subsequent years. A weaker effect is also seen on the number of claims given up, with elections increasing the level again in subsequent years. This highlights the importance of political cycles upon property rights to the forest in Guyana. There is also some weaker evidence of an effect of the introduction of REDD+ on the holding of rights. The introduction of REDD+ seems to have had a negative effect on the number of claims being taken out through the channel of prices. It also seems to have had a level effect on the number of claims being given up.

This provides some initial evidence of an effect of the introduction of a REDD+ policy framework upon forest management, through the holding of mining property rights, in Guyana.

Section 2 provides more depth on the situation in Guyana. Section 3 outlines a simple conceptual model for the taking out, holding and giving up of mining claims. Section 4 describes the data and Section 5 the econometric methodology. Section 6 provides the results of the econometric analysis and Section 7 discusses implications and concludes.

2. Guyana

Mining has grown rapidly in Guyana in recent years, increasing from 11% to 21% of GDP between 2006 and 2012 (Guyana Bureau of Statistics, 2013). Production has focused on gold and diamonds currently solely from small and medium-scale operators, conducted through river or land dredging.[4] It represents the largest driver of deforestation in the country, accounting for 93% of cleared forest in 2012 (Guyana Forestry Commission & Indufor, 2013).

2.1 Mining

Mining in Guyana is governed by the Mining Act 1989 which sets out the regulatory framework for the prospecting and conveyance of minerals. All minerals are the property of the State, and the Guyana Geology and Mines Commission (GGMC) is the body with the authority to grant licences or permits to search, mine, take and appropriate minerals. The Mining Act is supplemented by the Mining Regulations of 1973 ('Regulations'). In order to mine in Guyana a legal claim is required, defined by the Regulations as *'the area of State land in respect of which a concession is granted or a lease or license is issued'.*[5] These claims therefore are a property right for miners looking to undertake any sort of mining activity on a piece of land. Miners may hold claims for a number of reasons: because they want to undertake exploration on a piece of land; because they want to mine the land today; or because they want to mine the land at some point in the future. Claims are therefore both subject to current and potentially future mining activity –they may also have been subjected to mining activity in the past with miners looking to return to previously worked areas to extract gold from tailings using improved technology.

Claims are valid from the date of issue until the 31st of December of the same year, but can be renewed annually on application to the GGMC.[6] The Act gives the right to the Minister to declare any area of Guyana a mining district. There are currently six mining districts in the country, along

[4] For more detail on mining techniques in Guyana see Dalgety, (2010).
[5] Regulations *s2*
[6] Regulations s63 (2). Indeed as per s25 of the Regulations, '*Subject to the Act, every licence shall continue in force so long as the rent payable in respect thereof is regularly paid.*'

with a series of closed areas (Table 2). Claims are issued in each of these districts and are available in one of four types: Gold, Gold and Precious Stones, Precious Stones and River. The first three relate to land claims, and the type of minerals that may be extracted and sold through those claims. The fourth relates to a claim for a stretch of river to be mined.[7] The annual rental fees for these claims are shown in Table 1. In addition to these rental fees royalties are charged on all gold sold through the Guyana Gold Board at a rate of 5% and this rate has remained stable over the last twenty years.[8]

Table 1: Rental Fees for Mining claims and licences in Guyana 2013[9]

Source: Guyana Geology and Mines Commission (2012)

Mineral property / Licence Type	***Annual Rental fees***
Claim Licence to mine for gold and precious stones	G$ 1,000
Claim Licence to miner for valuable minerals	G$ 1,000
River Location Licence	G$ 2,000

2.2 Politics

Since independence in 1966 the political arena in Guyana has been dominated by two main forces, the ruling People's Progressive Party Civic (PPP-C) which held power from the first internationally deemed 'free and fair' elections in 1992 until 2015, and the People's National Congress/Reform (PNC-R) which held power between 1966 and 1992 (The Council of Freely Elected Heads of Government, 1993). Elections since 1992 have generally been accompanied by spates of post-electoral violence, most notably in 1992, 1997 and 2001 (Lowe, 2013). Guyana has only transitioned power between parties on three occasions in its history – the pre-independence 1964 elections where the PPP lost power to the PNC under the heavy influence of American and British interests (The Council of Freely Elected Heads of Government, 1993), the 1992 election which led to the PPP-C's return to power through elections supervised by Jimmy Carter (Hinds, 2005) and the 2015 transition from the PPP-C to the APNU/AFC coalition (consisting of the PNC-R and a wide range of smaller parties). In both the 1964 and 1992 elections there was a period of economic and social uncertainty following the changes. Between 1992 and 1997 the PNC accused the PPP of

[7] Regulations s2

[8] As per the provisions of the Guyana Gold Board Act the organisation is the main legal purchaser of gold in the country.

[9] The Guyana Dollar is equivalent to approximately US$0.05.

marginalising African Guyanese by engaging in ethnic witch-hunting in the public sector and discrimination in land distribution (Hinds, 2010).

2.3 REDD+

Guyana's REDD+ initiative, funded through an agreement with Norway, has been described as the one of the most advanced national-level REDD+ programme in the world, and is the second largest Interim REDD+ partnership (Office of the President, 2013). Finance is earned through Guyana maintaining a low deforestation rate, and meeting defined policy targets and is utilised to meet the objectives of Guyana's LCDS. The Strategy is built on a number of key strategic areas including renewable energy, support for low carbon business and adaptation (Office of the President, 2013). Projects implemented under the LCDS utilise the money earned via REDD+. There is currently no money earmarked for small-scale mining despite it being the largest driver of deforestation. Instead the government is targeting the sector via increased regulation, and crucially increased enforcement of existing regulation. This implies that although no specific financial incentives have been created for miners to change activity under REDD+ there has been a change in the overall regulatory environment.

3. Mining model

In order to understand how economic, regulatory, political and geographic factors have affected the holding of mining claims in Guyana, a conceptual model of the behaviour of miners is constructed. The model builds on literature relating to mining decision-making internationally (Slade, 2001), in Suriname (Heemskerk, 2001), and discursive literature identifying the factors driving ASM (Jønsson & Fold, 2011). The model focuses on a rational, profit maximising miner faced with the decision to take out, hold and then give up a mining claim for an identified parcel of land.[10] The model presented here is based on the concept that in Guyana miners essentially face a nested set of decisions – first whether or not to take out a mining claim, then subsequently whether (or when) to operate a mining operation on that claim, and then when to end the operation and give up the claim. Essentially there is flexibility in miners' decision-making at the investment level, the operation level (as in Slade 2001) and the divestment level. The model does not adopt the Hotelling rule (Hotelling, 1931), partially due to the difficulties in finding empirical evidence to back-up the approach (Kronenberg, 2008; Livernois, 2009), but also because the rule is based on a miner making decisions

[10] It is assumed that the identified parcel of land is available for a claim to be issued, and thus the government side of the decision making process is neglected. The assumption of a rational profit-maximising actor for the miner is one that could be called into question given the importance of small-scale mining as a source of livelihoods in many situations (Bryceson & Jønsson, 2010). However in Guyana the small-scale mining sector is dominated by a number of business operators who are more likely to behave as rational profit-maximisers (C. Y. Thomas, 2009).

regarding extraction rates (from a known level of reserve). The situation in Guyana, and with alluvial small-scale mining more generally, is different. Miners do not have knowledge on the level of reserve at mine sites – indeed for alluvial deposits this is almost impossible – and they do not make decisions regarding rate of extraction. The decision is in fact whether to start operations and cease with any minerals found in between basically based on chance. This background motivates the use of a model based on the option approach.

In the first year of the model the miner faces a decision of whether or not to take out a claim for a parcel of land and weighs up the discounted future anticipated profit stream against the cost of taking out the claim. This cost is both the fee involved[11] plus additional costs of undertaking the activities necessary to take out the claim (liaising with government departments, demarcating the claim, etc.). If profits streams are greater than costs then it is assumed that the miner takes out the claim. Discounted future anticipated profit streams, $E\pi$, are modelled as:

$$E\pi = \int_{t=0}^{T} \frac{E(\pi_t)}{(1+r)^t} dt \quad (1)$$

$$E(\pi_t) = \left(E(p_t^g) \times E(prod_t)\right) - E(Operating\ cost_t) \quad (2)$$

where:

- $E(\pi_t)$ is the expected profit at time t comprising:
- $E(p_t^g)$, is the expected price of gold in time period t
- $E(prod_t)$, is the expected production rate of gold in time period t
- $E(Operating\ cost_t)$, is the expected cost in time period t, encompassing fuel costs, labour costs, costs of compliance, fees payable to the government, etc.
- t is time period
- r is the discount rate
- T is the total time that a claim is expected to be held for

The probability that a claim is taken out is positively related to expectations of future gold prices and expectations of future production at that claim, and negatively related to expectations of future costs. It is also negatively related to the discount rate. The probability also depends on the expected length of time of production at a particular claim. Although regulatory factors may play a role through a number of channels the main avenue identified by previous literature on mining (Bhappu

[11] Claim licences to mine gold and precious stones have an annual rental fee of G$1,000 with river claims costing G$2,000.

& Guzman, 1995; Park & Matunhire, 2011) and investments generally (Clark, 1997) is the discount rate, with the general hypothesis that regulatory risk, through increasing uncertainty, decreases investment (supported by work such as Pindyck, 1988 with respect to irreversible investment and price uncertainty). However there is also a body of literature that has shown that the sign of the investment-price uncertainty relationship may actually be positive (Abel, 1985; Caballero, 1991; Hartman, 1972). As Caballero, (1991) highlights, whether this relationship is positive or negative depends on the nature of adjustment costs, risk aversion and completeness of markets. As this lies beyond the scope of this simple model, it is simply assumed here that regulatory risk (through creating uncertainty) has an effect on the probability of taking out a claim (i.e. investing in a property right), and also subsequently on giving up a claim (i.e. divesting from that property right). The sign of the effect is left ambiguous at this stage, with the empirical testing conducted in the latter stages of the paper testing first the existence of this effect, and secondly the sign.

From (1) and (2) the probability that a claim is taken out is a function of a number of factors

$$Prob(Takenout) = f\big(E(p^g), E(prod), E(operating\ costs), E(regulatory\ risk), E(taking\ out\ costs)\big) \qquad (3)$$

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Where:

- $E(regulatory\ risk)$ is the anticipated level of regulatory risk from events like elections, and the introduction of REDD+.
- $E(taking\ out\ costs)$ is the expected value of costs involved in taking out a new claim, including fees payable to the government and the costs relating to completing the regulatory process.

The first decision the miner faces in the year subsequent to taking out the claim is whether to continue to hold or to rescind the claim. It is assumed that the miner will hold the claim if, $E\pi$, is greater than rental costs (the annual rental fee plus any associated costs). If costs are greater than the profit stream then it is assumed that the miner will give up the claim.

If the miner decides to hold the claim the next decision is whether to operate the claim or not. A miner may hold a claim without operating as long as he meets the regulatory requirements.[12] He may delay operation while he undertakes exploration, clearance, or due to anticipated rises in prices

[12] The Commission may refuse renewal if it believes that mining operations have not been carried on, or that the holder does not intend to do so.

or decreases in costs. It is assumed that there exists a value from operating the claim in a given year, t:

$$Operating\ value_t = (E\pi \mid prod_t) + \pi_t \ (4)$$

where

$$\pi_t = (prod_t \times p_t^g) - operating\ costs_t$$

This can be generalised to the following condition that if satisfied implies that the claim will be operated:

$$\begin{aligned} Operating\ value_t &= (E\pi \mid prod_t, operating\ costs_t) + \pi_t > Holding\ value \\ &= E\pi - rental\ costs\ (5) \end{aligned}$$

Where $rental\ costs$ is the value of the costs associated with holding the claim but not operating it, such as the rental fees payable to government. The claim is held, thus, if:

$$E\pi | prod_{t-1} - rental\ costs > 0\ (6)$$

This can be generalised to:

$$E\pi | \sum_{t=0}^{n} prod_{t-1} - rental\ costs > 0\ (7)$$

for subsequent time periods. From (1), (4), (5), (6) and (7) the probability of a claim being given up in any year, n, is dependent on a number of factors:

$$Prob(givenup) = f\left(\left(E(p^g), E(prod)\ , E(operating\ costs), E(Regulatory\ risk)\right) \middle| \sum_{t=0}^{n} prod_{t-1} \right) (8)$$

(-) (-) (+) (?) (+)

Equations (3) and (8) highlight the main determinants of the decisions to take out and give up claims. The decisions have four common elements, expected prices, expected production, expected costs and expected regulatory risk. The decision to take out a claim also includes the costs involved in the process, while the decision to give up a claim includes the production history of that claim.

3.1 Expected prices

Miners' gold price expectations may depend on a number of factors such as the evolution and variation of previous prices and the level of knowledge of future price trends. Estimating such a complex function is however beyond the scope of this paper. Instead a simple model that expectations of future prices are based on current prices today is adopted. The Guyana Gold Board, the main purchaser of gold in Guyana, offers the international gold price to miners.[13] Expectations of future prices are thus modelled using the inflation-adjusted international gold price.[14]

3.2 Expected production

Expected production will vary on a range of claim and owner-specific factors such as the intrinsic level of reserve at the site, the location of the claim in relation to existing operations, the level of information that a holder has regarding the claim and the results of any exploration. Expected future production will also vary depending on the level of previous production at the site, with the anticipation that higher previous production will be accompanied by lower future production, given a fixed level of reserve at the claim. None of these variables are observable[15] so proxies must be sought. Age of claims held in a district in any year is used as a proxy for expectations of production. It is assumed that the longer claims have been in held in a district, the higher the expectations of production in the district as a whole. However there may be an opposing effect on the expected production of new claims. The longer claims are held in a district, the more likely that prime production land has been taken and therefore any new claims may have lower expected production. Thus it may be anticipated that age is negatively related with expected production for new claims, but positively related to expected production for existing claims.

For claims given up the model outlined above highlights the importance of the historic production of the mining claim in determining the likelihood of it being given up. This cannot be observed for each claim directly, or for the district as a whole. As a proxy however, the duration that the claims given

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[13] The price used by the Gold Board is generally the London price (Capitol News, 2013). The actions of the Gold Board are governed by the Guyana Gold Board Act (Government of Guyana, 1994). Although there are small legal and illegal gold purchasers in remote districts there is no data as to the prices that they offer and the variation over time in their prices is likely to follow international gold price movements.

[14] To test the assumption of the simple model of price expectation formations two alternative models were used. A three year moving average of gold prices was included to test the effect of the previous evolution of gold prices upon the incentives to hold and give up claims. In addition the volatility of gold prices within each individual year was computed by calculating the standard deviation of monthly gold prices. The lag of this volatility was included to test whether the volatility of gold prices plays a role in the incentives to hold mining property rights. The replacement of the annual gold price variable with the three-year averaged gold price variable makes little significant difference to the overall results. The price volatility variable was also found to be insignificant in all cases.

[15] Although the name of the owner of the claim can be elicited from the data used the nature of the mining industry in Guyana (based upon small and medium scale producers) means that no data is available that would allow estimation of owner-specific factors.

up are held for is used, with the hypothesis that the longer claims have been held for the greater the level of production at that claim. If claims are being given up with longer durations that may indicate it is due to previous levels of production, rather than other factors.[16]

3.3 Expected costs

The largest costs to a mining operation are labour and diesel (Heemskerk, 2001; Thomas, 2009).[17] Diesel in Guyana is imported through Trinidad and Tobago or Venezuela.[18] Although preferential terms are received for diesel purchased from Venezuela the price of diesel in Guyana tends to follow world market prices.[19] Thus to proxy domestic diesel costs global crude oil prices are used. No wage data is available for Guyana for the time period required therefore as a proxy real GDP per capita is used. This was used by Heemskerk (2001) to proxy job opportunities outside the mining sector, serving as a proxy for the opportunity cost of working within the mining sector and the level of wages demanded by workers to remain in the sector.

Rental fees and royalties in Guyana have remained stable in recent years (C. Y. Thomas, 2009). As these are fixed over the time-scale of the study they are not suitable for inclusion in the model, although they will form an element of rental and operating cost expectations.

3.4 Expected Regulatory Risk

There are two areas of regulatory risk of specific interest to the paper: elections and the introduction of REDD+. Elections may trigger risks relating to higher regulatory costs, affecting cost expectations; risks regarding expropriation; expectations of higher fees, or even the inability of government to process new claims or renew existing claims. The aftermath of elections may also see increased migratory activity as people leave the country leading to drop-off in the demand for claims. Elections occurred in Guyana in 1997, 2002, 2006 and 2011 and to capture the differential effects that elections could have a set of dummies are constructed representing the year before, the year of, and

[16] It should be noted that there might be a relationship between duration of claims in a district and the decision to give up claims. Although there cannot be a contemporaneous direct impact on the decision to give up a claim and the duration that all the claims in a district that were given up were held for (due to the way that duration is calculated, i.e. before that decision is made), there could be a lagged impact of the decision to give up claims in a previous period and the duration, and therefore an impact from an unknown variable that could impact both decisions. In these cases instrumental variables can be used to correct any bias that may occur (see Clarke & Windmeijer, 2012 for discussion in models with binary outcomes). The paucity of available data for mining in Guyana makes this approach impossible, with no other district-type specific variables available to estimate such an instrumental variable.

[17] Different miners will be subject to differing cost levels due to varying production functions and access to inputs. However these variations are unobservable and so a universal production function and level of costs is assumed across the industry.

[18] Guyana imports around 50% of its domestic oil consumption via the Petro Caribe agreement with Venezuela (Jacome, 2011)

[19] An analysis of monthly retail gasoline prices in Guyana and monthly global crude oil prices shows a correlation between the two of over 0.7 over the period 2009-2010

the two years immediately subsequent to election events. The nature of the regulatory system in Guyana where claims are only given up once annual fees have not been made implies a lag in the system, meaning that rescinded claims may only show up in years subsequent to the decision to rescind.

The second source of regulatory risk is related to the introduction of REDD+. This has led to uncertainty regarding the stringency of future regulations, the ability of miners to take out new claims and the potential costs regarding operations.[20] This is seen with the introduction (and subsequent removal) of new regulations relating to mining (Guyana Times, 2012; Kaieteur News, 2012; Stabroek News, 2012), statements from Ministers regarding enforcement and the establishment of new institutions.[21] Regulatory risk from REDD+ is included via a dummy which is 1 for the years post the start of the LCDS and 0 otherwise.[22] Further it is hypothesised that the introduction of REDD+ has fundamentally changed miners' future expectations, implying not only level effects, but also changing the model via interaction effects with other variables such as gold prices. One example of how this might occur is the fact that the introduction of REDD+ may potentially lead to requirements to undertake greater reforestation or rehabilitation of mined out areas after production has occurred. The costs to the miner of this activity are two-fold, first a fixed cost of the equipment and material required to undertake such reforestation, and secondly an opportunity cost in terms of the lost production that could be occurring whilst rehabilitation (such as backfilling mining pits) is undertaken. This second opportunity cost will be higher when prices are high as the value of the forgone production is greater.

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[20] As communicated to the author by two members of the Guyana Gold and Diamond Miners Association (GGDMA) Shields, E. (personal communication, March 3, 2012) and Sparman, C. (personal communication June 6, 2012)

[21] For example the Special Land Use Committee which is a body comprising government and non-government officials that was established to examine issues regarding mining, forestry and land-use,. It emerged after a protest by miners regarding the LCDS (Stabroek News, 2010).

[22] This approach risks capturing any other changes to the regulatory regime, or operating environment, contemporaneous with the introduction of REDD+. However to the author's knowledge no such other events have occurred. An alternative approach would be to proxy the establishment of REDD+ policy with the disbursement of REDD+ funds in the country. However Guyana has experienced significant delays in disbursing REDD+ finance, but has proceeded with changes in policy despite these delays, see Laing (2014). The approach may also be problematic if miners had anticipated the effect of the introduction of REDD+ policy, however this is unlikely to be the case given the rapid development of the policy in Guyana, and the lack of engagement of miners in the process, see Laing, (2014).

4. Data

The source of the unit of observations is the list of claim licences in existence and claims held published annually by the GGMC.[23] Data was compiled by the author from the hard copies of the Gazettes held at the Library of the GGMC. The Gazettes consist of the claims held as of December of the previous year including data on the type of claim, the district in which it was held and the year that it was taken out. Districts and Types are referred to by number as outlined in Table 2.[24] From the data extracted from the Gazettes the number of claims taken out in each district of each type for each year (*takenout*) can be observed (as the Gazette gives the year in which each claim was issued). The number given up (*givenup*) can be computed from the difference in the total number of claims between two years, factoring in the number of new claims. A summary of these variables is shown in Table 3. The observation of these allow estimation of the importance of the different factors identified in the model in Section 3 as affecting the probability of taking out or giving up claims to be tested. It should be noted that the estimation of the effect of these two variables separately ignores the possibility that the probability of taking out a claim may impact on the probability of giving up a claim. This may be the case if, for example, miners adopt a portfolio approach to their holding of claims – for example they may find a suitable claim they want to take out, and give up one of their existing properties in order to take out the new claim. However the nature of the data does not allow us to examine the portfolios of individual miners to understand whether this is the case and whether this occurs. Assuming the independence of the two events implies that miners treat each claim separately and on its individual merits based only on claim-specific information and prevailing conditions. Thus findings from this analysis are limited to impacts on claim-specific decision-making not on miners decisions on their overall portfolio.

From the data the age of the claims held in each district of each type could also be extracted along with the duration of the claims that were given up. Plots of the number of claims held per district and per type are shown in Figures 1 and 2 – these highlight that over the period of the study the number of claims held rose from just under 12,000 in 1996 to almost 16,000 at their peak in 2012.

[23] List of Claim Licences in Existence and Claims held, published by the GGMC in The Official Gazette (Extraordinary) of Guyana: Published by the Authority of the Government. As legally required by the Regulations s26 (1).

[24] The Gazette also contains the name of the claim owner and a short description of the location of the claim. It should be noted that the name of the claim owner does not always represent the ultimate claim owner or mine operator. Much of the industry in Guyana is family-owned and the claim owner in the Gazette is often a relation of the ultimate owner. In addition a number of claims are sub-contracted to other parties who make the ultimate decision of whether to operate or not. This difficulty further limits including miner-specific effects in the analysis, although they will undoubtedly have an effect and could be included through miner-specific fixed effects if it could be observed.

Claims are distributed across all six districts and four types, with only one district-type combination lacking any claims in 2012 (Gold -only in Berbice).

Table 2: Mining Districts and Types

District Number	District Name
1	Berbice
2	Mazaruni
3	Potaro
4	Cuyuni
5	North-West
6	Rupununi

Type Number	Type Name
1	Gold
2	Gold and Precious Stones
3	Precious Stones
4	River

Table 3: Summary of dependent variables

Variable	***N***	***Mean***	***S.D.***	***Min***	***Max***	***Number of zeros***
Taken out	408	49.32	85.03	0	561	128
Give up	384	43.35	79.13	0	648	90

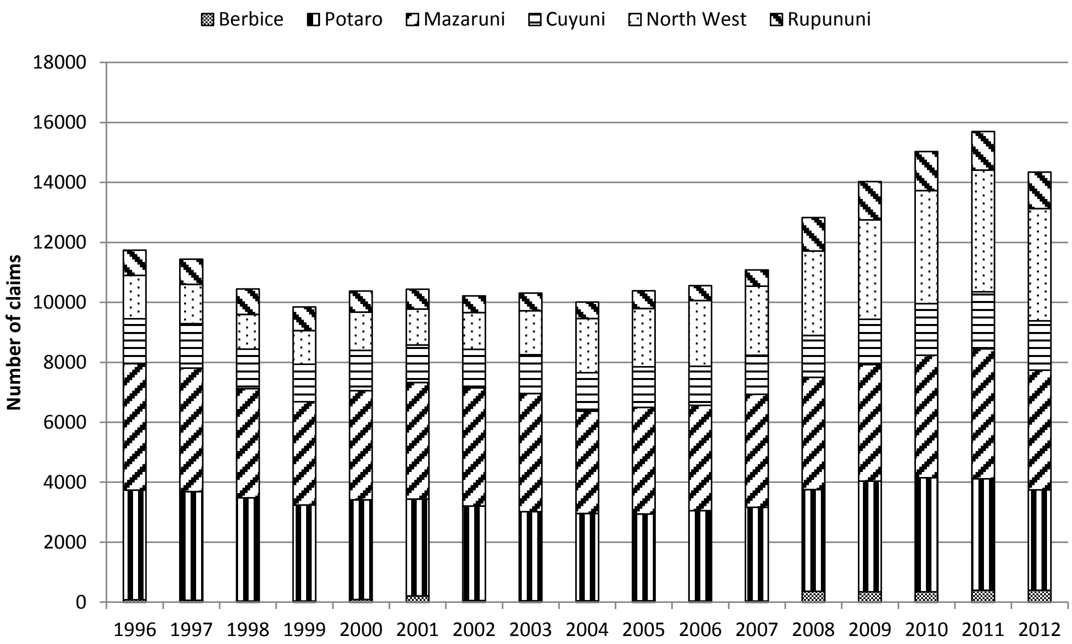

Figure 1: Number of claims held 1996-2012, by district

Source: The Official Gazette (Extraordinary) of Guyana

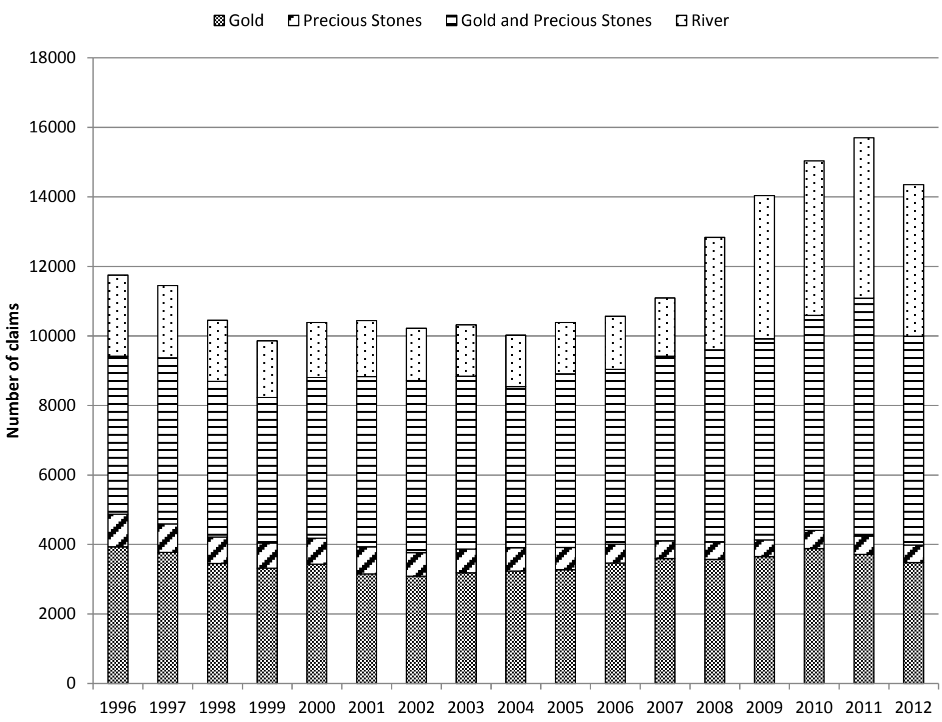

Figure 2 Number of claims held 1996-2012, by type

Source: The Official Gazette (Extraordinary) of Guyana

Gold price data is sourced from www.kitco.com and deflated using data from the IMF (International Monetary Fund, 2013). Oil price data is sourced from the BP Statistical Review 2013 (BP, 2013). Real GDP per capita data is sourced from the IMF (International Monetary Fund, 2013). A summary of the independent variables is given in Appendix 2.

The correlation of the independent variables was tested to ensure that any problems of multicollinearity are minimised. High correlation was found in the time period between the real gold price, real oil prices and real GDP per capita thus the changes in the latter two variables are used in the estimation rather than the level variable. This removes the trending that occurs between these two variables, and on further testing there was no correlation between real gold prices, the change in oil prices and the change in GDP.

5. Methodology

The unit of observation is a set of time-series cross-sectional (TSCS) count data. Data is observed for 17 years between 1996 and 2012. Observations are obtained for each of the six mining districts and each of the four claim types yielding a panel of 17 years by 24 individual district-type combinations. The fact that each of the district-type combinations is observed means that in any time-period the entire population is observed, there is no sampling, justifying a different approach from standard panel data methods that assume units are drawn from a much greater population. TSCS techniques draw more heavily on standard time-series analysis, and this is the approach adopted here, with controls for specific district-type effects included via a set of dummy variables.

A key issue with time-series data is stationarity - Breitung panel unit root tests (Breitung, 2000) rejected the existence of a panel unit root. Due to the count nature of the data however both dependent variables showed evidence of non-normality in both levels and natural log transformations via Shapiro-Wilk tests (Shapiro & Wilk, 1965). This creates problems with the use of possible estimation techniques for TSCS data such as Ordinary Least Squares (OLS) with Panel-Corrected Standard Errors (Beck & Katz, 1996). One alternative approach that could counter the non-normality would be the use of a negative binomial or Poisson models however such models prove difficult to incorporate dynamic elements, crucial for analysing time-series data (Brandt, Williams, Fordham, & Pollins, 2000 and Brandt & Williams 2001).[25] These techniques are suitable for independent, identically distributed data, but are problematic when there is dependence over time, as is the case with time-series cross-sectional data.

To incorporate both the count nature of data and dynamic elements Generalised Estimating Equation (GEE) models are adopted.[26] They allow for the assumption of independence to be relaxed, while allowing the non-normality of the assumed identical distribution to be preserved.[27]

GEE models require the definition of four items:

- The distribution of the dependent variable (this is defined in the model as the negative binomial)[28]

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[25] OLS and negative binomial models were run to validate results. The results from these estimations also broadly supported the predictions of the model. Full results are available on request.

[26] GEEs have been widely used in the natural sciences, especially medicine, to analyse situations where there are repeated observations on individuals over time, but are being increasingly applied in the field of political science (Zorn, 2001). They are a special class of Generalised Linear Models (GLM) that allow for correlation between observations, both over time and in clusters. GEEs also have the advantage that they can be used with a variety of models, both linear and non-liner, allowing the use of a negative binomial distribution to take into account the count nature of data. For a detailed discussion of GEE models and their application see Ballinger, (2004), Hanley, Negassa, deB Edwardes, & Forrester, (2003) and Hardin & Hilbe,(2013).

[27] It is assumed that the overall distribution from which number of claims given up or taken out in each year is identical across the time period, and is unchanged beyond the independent variables tested in the model.

[28] An alternative distribution would be the Poisson. This is more often used in count-data modelling (Winkelmann, 2008). It, however, requires more restrictive assumptions than the negative binomial, namely the equivalence of mean and variance. This often does not hold in practice – indeed here the dependent variables show much higher variance than means. Negative Binomial distributions have been used instead of Poisson models to deal with issues of over-dispersion, where variances are greater than means. To test whether the assumption of a negative binomial distribution was more suitable than a Poisson a likelihood ratio test was performed between count data models with no time-series component. These tests showed that a negative binomial outperformed the Poisson across both dependent variables and all specifications.

- The link function – this is the link between the response variable and the linear predictor (here the default option for the negative binomial, the log function, is used)
- The independent variables
- The covariance structure of the repeated data, the working correlation matrix. Using tests of Quasi-Likelihood Information Criterion,[29] evidence of persistence in the data for both dependent variables, and theoretical considerations that there is likely to be effects from shocks in one time period felt in latter periods, an AR(1) correlation structure is chosen for the working covariance matrix, along with robust standard errors.[30]

Technical details of the model's estimation are given in Appendix 1.

6. Results

Models are run for both *takenout* and *givenup* – one including the interaction term between LCDS and the gold price, and one excluding the variable. DFBETA's were calculated to identify whether the results were being driven by a small number of key observations – an important test in GEE models (Ballinger, 2004; Diggle, Heagerty, Liang, & Zeger, 2002).[31] There were no high values and thus there is no major concern that the results are being driven by any specific observations.[32]

Marginal R^2 are calculated for the GEE models (Zheng, 2000, Hardin & Hilbe, 2013). For *takenout* approximately 40% of the variance of the number of claims taken out are explained by the model. The *givenup models* do not perform as well with R^2 in the range of 0.09 to 0.28, indicating that other factors are driving the key decisions to give up claims beyond the model.

6.1 Number of claims taken out

The empirical evidence broadly supports the model presented regarding the number of claims taken out (Table 4). There is significant evidence of a positive effect of real gold prices on the level of claims taken out. Calculating the incidence rate ratio (IRR) from the GEE models the scale of this

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[29] The test used is based on the extension of Akaike's Information Criterion developed by Pan, (2001) for model-selection in GEE models. It was implemented using the qic test in Stata developed by Cui, (2007).

[30] An AR(1) process is given by: $X_t = \alpha + \beta X_{t-1} + \varepsilon_t$. AR(1) structures outperformed independent structures across all model specifications. Unstructured working covariance matrices did not lead to convergent models and thus could not be used.

[31] The DFBETA of any particular observation is the between the regression coefficient for an included variable calculated for the entire data set, and the regression coefficient with the observation deleted, scaled by the standard error calculated for the data set with the observation deleted (Rethemeyer, 2007). The statistics were calculated by dropping a specific district-type combination in order to test whether results were driven by any specific panel.

[32] For the *takenout* model there were four values on the cusp of the cut-off value ($2/\sqrt{N}$), three of which relating to Model 8 and one for Model 9. For the *givenup* model two values were on the edge of the cut-off, again one each for Model 8 and Model 9. None of these values was sufficiently high to cause major concern or to indicate that the results are being driven by a small number of observations.

effect can be seen: a US$1 increase in the real gold price leads to approximately a 0.1% increase in the quantity of claims being taken out.[33]

A significant negative effect of the age of claims is also found with a one unit increase in the age of claims (i.e. one year) reducing the quantity of claims taken out by around 25%. The inclusion of change in real GDP per capita and change in real oil prices as proxies for operating costs has no impact. The lack of significance may indicate either that the proxies were not adequate measures of the bundle of costs experienced by mine operators, or that costs play little part in the decision to take out new property rights.

The dummies for the year of elections and the year prior to elections are not significant, but for the years subsequent to elections there is a significant negative effect on the level of claims taken out, with significant effects seen also in the second year subsequent to elections. In years subsequent to elections, claims are reduced by between 33-55%. In the second year after elections this effect persists at approximately the same scale with claims reduced by 46-54%.

There is little evidence of a negative effect of REDD+ on the level of the number of claims taken out,[34] however once an interaction term between REDD+ and gold prices is introduced there is a significant, negative effect. The scale of this effect is relatively small: in years subsequent to REDD+ a US$1 increase in the gold price increases claims by 0.15% less. This finding seems to indicate that although REDD+ may not have served to increase regulatory risk absolutely, it may have changed the nature of decisions regarding prices. This may be because REDD+ has changed the time-horizon of miners, reducing the impact that future expectations of prices has upon whether to take out property rights or not or it has created expectations of having to undertake reforestation or rehabilitation (either today or in the future) – with the associated costs involved.

6.2 Number of claims given up

The empirical evidence regarding the model for the number of claims given up does not match the predicted model as closely as that for the number of claims taken out. The estimation of the effect of gold prices on the number of claims being given up shows a negative and significant effect (Table 4). The effect is small, with a reduction of 0.1-0.2% in claims given up, for a US$1 increase in the real gold price.

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[33] Incidence rate ratio is a ratio based on the incidence of counts. As described by Hilbe, (2008) it 'can be thought of as a ratio of ratios: i.e. the base ratio is the incidence rate of counts having some characteristic or property out of a group consisting of the population of subjects or items from which the counts are a part'.
[34] The effect is present across OLS models, but not under the ZINB and GEE specifications.

The model above predicted that the age of claims in the district of the relevant type will be negatively related to the number of claims taken out, however the variable is not significant. This raises questions as to the performance of the model for *givenup* and also the prior assumption that the age of claims is a suitable proxy for the level of anticipated production.

The variable included to proxy previous production of the claims given up, the duration of the claims given up, is predicted to be positively related to the number of claims given up. This is what is observed (see Table 4). Calculating the IRR shows the relatively small size of this effect - a one year increase in the duration of claims being given up increases the number of claims being given up by 3.3%. As in the model for the number of claims taken out neither the change in real GDP per capita, nor the change in real oil prices has any significant effect on the number of claims given up.

The election dummy shows a significant and positive effect on the number of claims given up (Table 4). In election years the number of claims given up is approximately 109% higher on average. There is no significant effect in the years prior to elections; however there is a positive significant effect on the number of claims given up in the years subsequent to elections. The IRR varied between 194% and 285% more claims given up than in other years. The effect in the second year after elections is weakly significant and positive in one of the models, with an IRR of around 77%.

The dummy for the years subsequent to REDD+ is positive and significant, as predicted (Table 4). The effect is relatively large with the number of claims given up in the years subsequent to the introduction of the LCDS around 300% higher than in years prior to REDD+. The inclusion of an interaction term between REDD+ and the gold price complicates the picture somewhat but still indicates a positive effect from REDD+ - the level effect of REDD+ is not significant, however the interaction terms is positive and significant.

Table 4: Model Results[35]

	Claims taken out			*Claims given up*	
Real gold price	0.00132* (-2.25)	0.00186** (2.88)		-0.000947** (-2.62)	-0.00192*** (-4.43)
Age	-0.257*** (-6.73)	-0.255*** (-6.91)		0.0117 (0.41)	0.0174 (0.64)
Duration				0.0324** (2.65)	0.0395** (3.06)
Election	-0.368 (-1.51)	-0.189 (-1.04)		0.733* (2.46)	0.505 (1.74)
Election lag	-0.178 (-1.47)	-0.0629 (-0.67)		0.323 (1.11)	0.208 (0.72)
Election plus	-0.536* (-2.50)	-0.355* (-2.20)		1.350*** (4.29)	1.080*** (3.54)
Election plus 2	-0.537*** (-3.34)	-0.459** (-2.93)		0.572* (2.06)	0.447 (1.88)
LCDS	-0.737 (-0.99)	0.714 (1.05)		1.388*** (3.92)	-1.050 (-1.70)
LCDS * Price		-0.00150* (-2.12)			0.00256*** (4.17)
District 2	4.110*** (-9.27)	4.106*** (9.00)		2.630*** (4.81)	2.500*** (4.70)
District 3	4.539*** (-8.78)	4.547*** (8.60)		2.932*** (5.41)	2.832*** (5.38)
District 4	3.274*** (-7.27)	3.308*** (7.13)		1.959*** (3.83)	1.824*** (3.69)
District 5	3.341*** (-4.53)	3.353*** (4.50)		2.372*** (3.84)	2.326*** (3.77)
District 6	2.825*** (-4.25)	2.837*** (4.15)		2.231*** (3.54)	2.131*** (3.46)
Type 2	0.683 (-1.66)	0.746 (1.80)		0.765* (2.38)	0.719* (2.18)
Type 3	-1.172 (-1.83)	-1.129 (-1.75)		-1.671*** (-3.58)	-1.718*** (-3.72)
Type 4	0.582 (-1.13)	0.558 (1.08)		-0.126 (-0.36)	-0.232 (-0.66)
N	405	405		382	382
R^2	0.414	0.423		0.156	0.089

7. Discussion

This paper provides the first study into the effect of election cycles, and REDD+, on forest-related property rights. It also provides one of the first studies of the effect of a national REDD+ framework on the behaviour of forest actors. The collection and use of a globally unique small-scale mining data

[35] The coefficients from the GEE model can be interpreted as the marginal effects for at the population level. Robust t-statistics are given in brackets.

set provides an important addition to the discussion on the evolution of small-scale mining, which has previously been qualitative in nature. Estimation through GEE regressions generally finds a negative effect of political events and the introduction of REDD+ on the taking out of property rights and a positive effect on the giving up of property rights.

The finding that elections affect the holding of property rights only in their aftermath hints at the possibility that the negative effect on the holding of property rights stems more from the post-electoral uncertainty that Guyana has experienced rather than the election event itself. Elections in Guyana have tended to be held towards the end of the calendar year, thus any post-election uncertainty is more likely to arise in the subsequent year rather than the year of the election. Whether the negative impact on holding of claims is due to fears of expropriation, expropriation itself, a lag in the regulatory system causing election year events to appear in the data from later years, a greater willingness of the government to rescind defaulting property rights subsequent to elections rather than before, changed long-term expectations of the regulatory environment, or an increase in migration patterns reducing the demand for new claims and encouraging the rescinding of existing ones is an interesting question. Evidence for the increase in migratory activity leading to a changed in incentives to hold property rights is given by anecdotal evidence communicated to the author by miners and mining families in Guyana, and also from migration data. The number of legal permanent residents entering into the United States (the main destination for Guyanese migrants) from Guyana shows two distinct spikes in and around the elections of 2001 and 2006 (United States Department of Homeland Security 1999, 2009, 2012).

There is also evidence that the introduction of REDD+ has reduced the incentive to hold forest-related property rights in Guyana. The fact that there is weak evidence of an effect of REDD+ on the holding of property rights, despite the fact that there is no specific policy within the strategy aimed at this highlights the potential of REDD+ policy to have unintended effects through other sectors of the economy by shifting expectations of property rights holders. It highlights the potential impact of national level REDD+ policy across a wide variety of sectors in the economy who directly, or indirectly impact on the forest. REDD+ in Guyana, however, is still in its infancy and as there are only four years of data for post-REDD+ activity available the reliability of these results is questionable. As more years of data emerge the strength of findings should become stronger. One option for extending the work is to transform the data into a set of duration observations, where the length that each individual claim is held for is computed. This is possible with the current data-set, though is computationally burdensome, and without more claim-specific variations in data whether further interesting results are obtainable is questionable.

The paper also raises a number of interesting questions regarding the evolution of small-scale mining. The paper highlights the important role of various political factors, along with economic factors, in driving the decision-making of small-scale miners in the holding of property rights. The findings cast some insight on the market affecting small-scale miners – highlighting the importance of regulatory certainty and political stability. Guyana's mining sector and regulatory environment is unique in the world, with stronger property rights for small operators than many other countries and a sector dominated entirely by ASM and therefore how applicable the findings of this paper are to other ASM environments is an interesting question. As the first type of detailed quantitative analysis of ASM property rights globally the insights from the paper raise interesting questions regarding the behaviour of ASM actors across the world. On the other hand the unique nature of Guyana does cast questions as to how applicable findings are to countries with less developed rights structures. However with more and more countries moving to develop more advanced rights structures the insights regarding how these many be managed in the wake of political and policy uncertainty may be useful lessons in creating stable regulatory and therefore property rights environments for small-scale mining.

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Appendix 1 : Model estimation

To estimate the model if we let $Y_i = [y_{i1}, y_{i2}, \dots, y_{iT}]$ be a column vector of observations of dependent variable for district-type combination, i, up to time period *T*, $\boldsymbol{X_i}$ be a $T \times k$ matrix of covariates for observation i and $E(Y_i) = \mu_i$ then:

$$\mu_i = h(\boldsymbol{\beta X_i}) \ (11)$$

where the inverse of h is the 'link' function. The vector of estimated parameters, $\boldsymbol{\beta}$, is estimated using quasi-likelihood methods as the solution to a set of k 'quasi-score' differential equations:

$$U_k(\boldsymbol{\beta}) = \sum_{i=1}^{N} \boldsymbol{D}_i' \boldsymbol{V}_i^{-1}(Y_i - \mu_i) = 0 \ (12)$$

where $\boldsymbol{D_i} = \boldsymbol{\mu_i / \beta}, V_i$ is the variance of Y_i, given by:

$$V_i = \frac{(A_i)^{1/2} \boldsymbol{R}_i(\boldsymbol{\alpha}) \ (A_i)^{1/2}}{\phi} \ (13)$$

where $\boldsymbol{R_i}(\boldsymbol{\alpha})$ is a $T \times T$ working correlation matrix across time, t, for a given $\boldsymbol{Y_i}$ and A_i are $T \times T$ diagonal matrices with $g(\mu_{it})$ as the *t*th diagonal element - the elements of $\boldsymbol{X}_i$ are varied in different model specifications.

Appendix 2 Descriptive statistics of variables

Name	Definition	Mean	Standard Deviation	Min	Max	Unit of measurement	Source
Real gold price	Deflated gold price	676.86	537.78	242.27	1923.97	US$	Kitco.com, IMF
Age	The average age of claims in the same district of the same type	8.93	5.42	0	22.71	Years	GGMC
Duration	The length of time claims that were given up were held for.	5.65	6.24	0	44.2	Years	GGMC
Election (Lag, Plus, Plus 2)	Dummy variable 1 in years of election (or year before election for lag, and year after for plus, and 2 years after for plus 2) 0 otherwise.						
LCDS	Dummy variable 1 in years subsequent to the start of REDD+ policy in						

	2008, 0 otherwise						
District	Dummy variables 1 if claim is in that district, 0 otherwise						GGMC
Type	Dummy variables 1 if claim is of that type, 0 otherwise						GGMC