

# The roles of network embeddedness, market incentives, and slack resources in clean technology adoption by firms in developing countries

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## **Abstract**

Worldwide carbon dioxide emissions continue to increase driven by fossil fuel consumption and industrial discharges. Progress on carbon emission reduction requires firms to adopt clean technologies which minimize material and energy consumption. Technological change is particularly required in developing countries, where industrial emissions often lead to chronic urban pollution problems. In this study, we explore the antecedents of clean technology strategy by firms in developing countries. We combine the contingent natural resource based view with the relational view to examine how network embeddedness, market incentives and slack resources influence adoption of clean technology. The empirical support for our hypotheses comes from data obtained from 342 firms that operated in the carbon-offset market during the years 2007 to 2009. We find that a firm's relational network structure influences adoption of clean technologies, particularly when market incentives are low. Contrary to one of the hypotheses, the results of our paper suggest a negative relationship between a firm's slack resources and its clean technology strategy. Our study highlights the benefits of networks in fostering adoption of clean technology in developing countries. Furthermore, we find that high market incentives (carbon price) decrease the probability of clean technology adoption, so adding to the view that firms respond to carbon offset rules to realise high carbon revenues at the lowest cost.

**Keywords:** Adoption of clean technologies, carbon-offset market, slack resources, network embeddedness, market incentives

## **1. Introduction**

Carbon dioxide (CO<sub>2</sub>) levels averaged more than 410 parts per million in April and May of 2018, and were the highest monthly averages ever recorded (National Oceanic and Atmospheric Administration, 2018). Worldwide CO<sub>2</sub> emissions have been increasing driven mainly by fossil fuel and industry emissions (Peters et al., 2017; National Oceanic and Atmospheric Administration, 2018). There is general agreement that achieving real progress and reductions on greenhouse gas emissions will require far-reaching technological change (Grubb, 2004). Firms, being the primary actors, are expected to reduce their carbon footprint by adopting clean technologies aimed at minimizing material and energy consumption (Hart & Dowell, 2011). Adoption of environmentally friendly clean technologies is particularly required in developing countries, where economic growth has resulted in increased emissions often leading to chronic urban pollution problems (Pfeiffer & Mulder, 2013).

In line with the natural resource based view (NRBV) of the firm, ‘greening strategies’, such as pollution prevention, result in incremental improvement and cost savings in the short-term (Hart, 1997; Sharma & Vredenburg, 1998). However, a longer-term sustainability strategy, which includes investment in clean technology, is necessary if economic growth is to be maintained into the future (Hart & Dowell, 2011). From this perspective, firms who want to better position themselves vis-à-vis competitors and who are motivated by future performance benefits are likely to invest in clean technology (Hart & Dowell, 2011; Jeswani, Wehrmeyer, & Mulugetta, 2008). However, as outlined by Aragón-Correa & Sharma (2003) the adoption of a clean technology strategy may also depend on moderating conditions or contingencies in the business environment.

Factors such as state and organizational effect uncertainty, complexity and munificence (the extent to which the business environment can sustain firm growth), are likely to hinder adoption of a clean technology strategy. Extant literature on the adoption of clean technology by firms in developing countries largely supports the contingent (natural) resource-based view, with internal as well as external factors found to be influential (Leonidou, Christodoulides, Kyrgidou, & Palihawadana, 2017; Slawinski, Pinkse, Busch, & Banerjee, 2017).

The current literature on firm adoption of clean technologies mostly considers firms as autonomous entities and overlooks the set of relationships that a firm has with other organizations (Ashraf, Meschi, & Spencer, 2014). The relational view posits that resources may span firm boundaries (Dyer & Singh, 1998) with external resources, to which the firm has access, embedded in its alliance network. The adoption of a clean technology strategy also requires resource-intensive innovation (Ahuja, Lampert, & Tandon, 2008; Frondel et al., 2007), which may be in excess of the resources we could reasonably expect a firm to possess, especially in a developing country context (Ashraf et al., 2014). Likewise, diffusion of clean technology amongst firms involves the transfer of information and has elements of innovation (Kemp & Volpi, 2008). Relational resources become even more important in developing countries (Khanna, Palepu, & Sinha, 2006), where a lack of institutional support systems may mean that firms rely on informal governance mechanisms including network embeddedness (Ashraf et al., 2014). Moreover, industrial innovation in developing countries has been described as highly informal (Arocena & Sutz, 2000; Pietrobelli and Rabellotti, 2011) with scientific knowledge and technological innovation often undervalued by dominant cultural patterns. Innovative strengths can remain isolated and encapsulated so making it

difficult for firms to build clean technologies in-house. Networks can thus enhance or provide capabilities that firms can access to deploy cleaner technologies since there is a lower reliance on in-house expertise in new technologies. However, the literature currently sheds little insight on the role of firm networks in the adoption of clean technologies, although it has been shown that such networks can affect carbon performance (Ashraf et al., 2014).

Likewise, the contingent resource based view (Aragón-Correa & Sharma, 2003) does not consider the impact of conditions in the general business environment on firm networks (Wasserman & Faust, 1994), or the impact of network-level cooperation, communication and learning on firm environmental behaviour (Inkpen & Tsang, 2005; Jarillo, 1988). Uncertain business conditions or low market incentives moderates the relationship between firm resources, including network related resources, and the likelihood that a proactive environmental strategy will be adopted (Aragón-Correa & Sharma, 2003). Therefore, even firms with access to a similar set of financial or relational resources are unlikely to have the same strategic approach where conditions in the business environment differ. However, we still do not have full grasp of how these contingencies influence firm behaviour.

In order to address these gaps in the literature, we build on, but also extend, the contingent (natural) resource-based view of the firm (Aragón-Correa & Sharma, 2003; Hart, 1995; Hart & Dowell, 2011; Sharma & Vredenburg, 1998) by simultaneously engaging with the relational view (Dyer & Singh, 1998). By cross-fertilizing these two theoretical frameworks, we explicate the role of firm resources and network structure on the adoption of clean technologies under uncertain business conditions in a developing country context. Using this combined theoretical lens, we offer

more clarity on the antecedents of clean technology strategy than either theoretical view can offer independently. Our work also contributes to the literature on the role of networks in firm climate change strategy (Ashraf et al., 2014).

The empirical support for our hypotheses comes from data obtained from 342 firms that operated in the carbon-offset market during the observation years of 2007 to 2009. In the following sections, we briefly present our hypotheses to explicate the underlying mechanisms of the adoption of clean technologies by firms. This is followed by method and results sections. The article concludes by discussing the theoretical and practical implications giving directions for future research.

## **2. Theoretical framework and hypotheses**

Cross-fertilizing the relational view with the contingent natural resource based view of the firm as described in the previous section, we develop hypotheses to explicate the effects of firm resources, network, and moderating conditions, on the adoption of clean technologies. We posit that resources owned by the firm influence its clean technology strategy. Moreover, considering the institutional voids in developing countries, we expect that firms rely more on their relational resources and network to access and adopt clean technologies. However, this is contingent on general market conditions.

### *2.1. Firm slack resources*

Nohria & Gulati (1996, p. 1246) define slack as “the pool of resources in an organization that is in excess of the minimum necessary to produce a given level of organizational output”.

While there are different types of slack, including, for example, human resources or operational capacity (Leyva-de la Hiz, Ferron-Vilchez, & Aragon-Correa, 2018; Voss, Sirdeshmukh, & Voss, 2008), our work follows that of researchers who focus on the availability of financial slack (Berrone, Fosfuri, Gelabert, & Gomez-Mejia, 2013; Waddock & Graves, 1997). Financial slack can be in the form of unabsorbed cash or credit lines or may be absorbed in the form of excessive investments in ongoing operations. Financial slack can typically be redeployed within the firm without significant constraint (Voss et al., 2008).

There are diverging views in the literature on whether absorbed and unabsorbed financial slack fosters firm innovation, noting that innovation is important for the adoption and diffusion of clean technologies (Ahuja et al., 2008; Kemp & Volpi, 2008). Several researchers highlight that the existence of financial slack helps in the allocation of investment to innovative projects (Leyva-de la Hiz et al., 2018; Damanpour, 1991) while too little slack is likely to inhibit innovation (Nohria & Gulati, 1996). Although investment in environmental innovation is considered to pose more risk

(Berrone et al., 2013), research finds that companies increasingly identify environmental innovation as bringing long-term strategic opportunities (Huang & Li, 2017). While there is no guarantee that such risky investments will translate into improved financial performance (Leyva-de la Hiz et al., 2018), this cushion of financial resources can protect the organization in the event of failure (O'Brien, 2003). In contrast, firms with low levels of financial slack are more likely to conserve resources to ensure availability of funds to maintain ongoing activities (Voss et al., 2008).

An alternative view in the literature is that firms use slack resources to sustain their operations rather than investing in innovation (Lavie, Stettner, & Tushman, 2010; Voss et al.,

2008). In such cases, firms may prefer to capitalize on established competencies rather than risk more innovative investments. Such resource rich firms may experience a lower motivation to innovate compared to those companies whose survival depends on their ability to find new ways to compete, since they may feel more secure about their ability to finance operations into the future (Lavie et al., 2010; Kraatz & Zajac, 2001)

From the above, it is apparent that financial slack may both facilitate and mitigate innovation. However, an important determinant in the decision to deploy resources is the perceived environmental threat (Lavie et al. 2010, Voss et al., 2008). Where the current as well as the long-term performance of the firm is threatened, then companies with greater levels of slack are more likely to deploy these resources, since innovation in this context is deemed to be salient (Voss et al., 2008). The need to transition to a low-carbon economy can be considered an important threat to companies in developing countries. Developing countries are being asked to transition to low carbon energy sources at a faster rate than developed countries have previously done (Kim, 2018). The requirement for developing countries to ‘leapfrog’ in their energy transition demands the development and transfer of advanced technologies (Kim, 2018). Firms that do not participate in this energy and technology transformation are likely to struggle to compete in the longer term as their processes become outdated and obsolete. Research has found that, although financial return is an important consideration for investment in low carbon technologies by firms in developing countries (Schneider, 2009), policy incentives, competitive position and reputation are also important motivators (Hultman, Pulver, Guimarães, Deshmukh, & Kane, 2012). This implies that firms in developing countries also consider the broader, long-term business implications of their

investments. Considering this, we posit that the more slack resources a firm has, the more likely it will be that it will invest and adopt clean technologies.

**Hypothesis 1:** *In developing countries, the higher the slack resources of a firm, the higher the probability that it will adopt clean technologies.*

## *2.2. Embeddedness in closed networks*

Institutions consist of both informal constraints (customs, traditions, codes of conduct) as well as formal rules (laws, constitutions) which create order in market exchanges (North, 1991). Particularly in developing countries, institutions may be weak or absent creating institutional voids. These voids include a lack of rules, regulations or law enforcement, underdeveloped or absent infrastructure, a lack of skilled labour or poorly functioning government agencies (Khanna & Palepu, 1997). Where institutions are weak or absent these voids generate uncertainty and barriers in the business environment (Mair, Martí, & Ventresca, 2012; Webb, Kistruck, Ireland, & Ketchen Jr, 2010). As a case in point, the institutional environment provides the necessary support for fostering and developing innovation (Metcalf & Georghiou, 1997) and research has found that where institutions are weak or absent then firm innovation is negatively impacted (Zhu, Wittmann, & Peng, 2012; Chadee & Roxas, 2013). Institutional voids in this context include weaker protection of property rights, low levels of research and development, and a small number of intermediaries that could connect research and development laboratories with the market (Khanna et al., 2006).

Given weak formal institutions, firms in developing countries often rely on informal institutions and relational trust mechanisms (Puffer, McCarthy, & Boisot, 2010) to bridge institutional voids. For example, in China, businesses rely strongly on *guanxi*, which are



connections or relationships based on reciprocity, to achieve their goals (Puffer et al., 2010). Similarly, Tariq, Badir, Tariq, & Bhutta (2017) argued that resource sharing and knowledge transfer through firm relational networks is important for the adoption of greening product and process innovation. Networks thus substitute or complement the formal institutional system in developing countries.

Coleman (2000) argued that trust between firms is a function of a particular network configuration, that is, a closed network wherein all of a firm's partners are connected with each other. Such a network ensures a social policing mechanism (Granovetter, 1985) to overcome the lack of trust, so giving credence to parties involved that commitments will be honoured. Where trust is high, firms are more likely to invest in learning and share valuable knowledge (Dyer & Singh, 1998; Inkpen & Tsang, 2005). A firm's closed network can thus increase access to knowledge which can also foster exchange as well as transfer of technologies (Inkpen & Tsang, 2005). Moreover, such a network enables actors to develop a common language, which facilitates the exchange of institutionalized routines, and tacit and proprietary knowledge, thus giving competitive advantages to all network members. Therefore, if a firm in a developing country is embedded in a closed network such that all its partners are connected with each other, institutional voids will be bridged. Under such circumstances, we posit that firms are likely to have access to knowledge and resources and so are more likely to adopt clean technologies.

**Hypothesis 2:** *In developing countries, the more a firm is embedded in a closed network, the higher the probability that it will adopt clean technologies.*

### *2.3. Market incentives*

It has been argued that economic incentives are important for technological change as they smooth the way for companies to invest in green innovation (del Río González, 2005; Tariq et al., 2017). Market incentives for adoption of clean technologies may include tax incentives, bank financing at lower rates, lower insurance premiums, and grants for research and development amongst others (Aragón-Correa & Sharma, 2003). The economic incentives associated with policy instruments, for example emission trading or carbon credits, can also be important in influencing investment in low carbon technologies (Wordsworth & Grubb, 2003). In the context of developing countries, the sale of carbon credits is likely to provide an important incentive for investment in clean technologies (Trotter, da Cunha, & Féres, 2015). In order to benefit from carbon credits under emissions trading, for instance, projects are expected to offer real emissions reductions as well as benefits to host countries, such as the transfer of technology and know-how (Fischer, 2005; Gillenwater and Seres, 2011). While in some cases it has been found that carbon credit revenues are just the ‘icing on the cake’ rather than the reason to undertake a clean technology project (Ellis & Kamel, 2007; Hultman et al., 2012) in other cases the project would not occur without carbon credit revenues (Schneider, 2009).

Under uncertain business conditions with lower market incentives, one would expect an increase in transaction costs and risk premiums that affect major capital investments. Given that investments are often hinged on expected rewards, any downward trend in market incentives increases business uncertainty, and so can dissuade investors from adopting a clean technology strategy. For example, Lee and Klassen (2016) found that uncertain business conditions decrease the adoption of carbon management practices. Since firms are expected to increase economic

rewards for their stakeholders, primarily shareholders, this requires that firms focus on responding to market demand (Tariq et al., 2017). Therefore, if the market signals that investments in clean technologies can translate into higher returns, firms are expected to adopt clean technologies (Aragón-Correa & Sharma, 2003). Therefore, we posit that:

**Hypothesis 3a:** *In developing countries, the higher the market incentives, the higher the probability that firms will adopt clean technologies.*

As investments can turn into higher rewards during high market growth and certainty (Chen, Zeng, Lin, & Ma, 2017), as signalled by high market incentives, relying on closed networks can become a liability. The closed network builds trust and facilitates exchange of tacit knowledge; however, it also reduces the possibility that firms will adopt an independent strategic posture (Ashraf et al., 2014). To reap short-term financial gains, control and independence over strategies cannot be ensured through closed networks. On the contrary, when the market is down or during low munificence (Aragón-Correa & Sharma, 2003), as signalled by lower market incentives, firms react differently. Market uncertainty, due to variation in incentives, is external and beyond the control of a specific firm. Under such circumstances, we argue, firms will reinforce the embedded relationships (Beckman, Haunschild, & Phillips, 2004) so as to share the risks and develop trust. This banding together also means that firms can focus on long-term financial rewards, since they are more likely to rely on forming closed networks, trading control for trust. This is also a less costly strategy compared to expensive acquisition of equity stakes (Kristinsson & Rao, 2008; Deng, 2009) with foreign partners. Therefore, we posit that:

**Hypothesis 3b:** *In developing countries, the lower the market incentives, the more likely it will be that those firms that are embedded in closed network will adopt clean technologies.*

### 3. Method

#### 3.1. Sample and data

Global climate policy relies on emissions trading to stimulate development of technologies for the transition to a low-carbon economy. An important component of this market is the Clean Development Mechanism (CDM) under the Kyoto Protocol<sup>1</sup>, which comprises approximately 7,700 projects with more than 1.6 billion Certified Emission Reductions (CER) issued (Cames et al., 2016). International market based environmental policies can create an incentive for firms in developing countries to invest in low-carbon technologies since this can result in financial benefit in the form of CER revenues as well as generating positive reputation among stakeholders (Hultman et al., 2012). We focus on the carbon-offset market as an empirical context. The carbon-offset market gives opportunities to firms in developing countries to learn, and access knowledge, technologies, and resources from their partners in developed countries (Ashraf, Ahmadsimab, & Pinkse, 2017; Ashraf et al., 2014; Huang & Barker, 2012; Kolk & Mulder, 2011). However, the

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<sup>1</sup> The future of the CDM is uncertain after 31 December 2020, when the Kyoto Protocol's second commitment period ends. Article 6 of the Paris Agreement introduces a new mechanism which aims to contribute to the mitigation of greenhouse gas emissions and to foster sustainable development. It is unclear whether the CDM will be discontinued after 2020, or whether it will remain operational in parallel to the Article 6 mechanism (UNFCCC, 2018).

price of carbon-offset rights influences emission reduction efforts in developing countries due to higher perceived risks or transaction costs.

To test our hypotheses, we used data that was collected as part of a large research project to understand the social and strategic dynamics of actors' behaviour in the carbon market during the years 2005 to 2010. The larger dataset comprised 1312 organizations representing 39% of the total organizations whose projects were registered in the CDM registry. These organizations were working on 1500 projects and belonged to 59 countries. The majority of firms belonged to China and India from the electric services and the cement industry. For this paper, due to unavailability of firm-level financial information, however, our sample consists of a subset of the larger dataset and comprises 342 firms belonging to 119 industries and 33 developing countries during the years 2007 to 2009 in the carbon offset market. Mirroring the statistics of the larger dataset, the majority of firms in our sample belonged to China and India from the electric and cement industries (see Table 1 for details).

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Insert Table 1 about here  
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The observation period of this study, although not recent, is ideal for understanding the behaviour of firms in the initial phase of the carbon-offset market during uncertain business conditions. Considering that many countries have started local and regional emission trading markets only recently, our study may provide empirical evidence to understand climate change strategies of firms during the institutionalization phase of carbon markets. The period of our sample 2007-2009 also encompasses the period between phase I & phase II of the EU Emissions Trading

Scheme (EU ETS), an important period which saw considerable market volatility. In 2007, and so towards the end of phase I, as a result of a market surplus, EU allowance (EUA) spot prices fell to 1€/tCO<sub>2</sub> and ended 2007 at 0.02 €/CO<sub>2</sub> (Alberola & Chevallier, 2009). In phase II, EUA prices reached a high of €28 by July 2008 (Capoor & Ambrosi, 2008; Mansanet-Bataller, Chevallier, Hervé-Mignucci, & Alberola, 2011), but the economic downturn later that year resulted in reduced demand, and carbon prices declined by almost 75% over a period of just a few months (Capoor & Ambrosi, 2009). By February 2009, EUAs were priced at €8 (Mansanet-Bataller et al., 2011) and by May of that year, prices had stabilized in the region of €13 to €16 (Kosoy & Ambrosi, 2010). Between mid-2009 and July 2011, prices remained stable but then dropped substantially (Silver, 2015). Between 2011 and 2017, EUAs were priced between €3 and €9 while CER prices plummeted and were worth less than €1 (World Bank Group, 2014, 2015, 2016, 2017). Therefore, the period of our study from 2007 to 2009 represents a unique period in the history of the EU ETS where both very low (<€1) as well as record high (€28 for EUA/ €22 for CER) market incentives were present within a condensed period of time. The carbon market data was obtained from the Institute for Global Environmental Strategies<sup>2</sup> and CDM Pipeline<sup>3</sup>. Financial data of the firms in the network were obtained from MINTGLOBAL<sup>4</sup> database.

### 3.2. Variables

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<sup>2</sup> CDM Project data can be accessed from Institute of Global Environmental Strategies from this address: <https://pub.iges.or.jp/pub/iges-cdm-project-database>.

<sup>3</sup> Complete historical record and analysis of the CDM market can be obtained from this address: <http://www.cdmpipeline.org/>

<sup>4</sup> Mintglobal (<https://mintglobal.bvdinfo.com>) is a proprietary database and contains financial information about the private and publicly listed firms.

We computed the dependent variable *adoption of clean technologies* as a proportion of renewable energy (biogas, biomass, wind, and hydro) projects of a firm in its carbon-offset projects portfolio during the observation years. There were three motivating reasons for selecting this proxy. First, this variable captures firm commitment to wean off non-renewable technologies and reduce its carbon footprint by exploring and investing in sustainable energy (Ashraf et al., 2017). Secondly, the variable signals a socio-technical shift in firm approach towards sustainability (Geels, 2010). Finally, firm carbon management practices are ranked highly by the market, and are considered as an indicator of environmental performance. Flammer (2013), for example, operationalized environmental performance using the KLD<sup>5</sup> index which gives considerable weight to firms' usage of renewable energy.

The *slack resources* of a firm influence its climate change strategy (Chen et al., 2017), as discussed above. We followed the existing literature (Waddock & Graves, 1997), and used the financial performance indicator - *return on assets* - as a proxy for slack resources.

To compute *network embeddedness*, we extracted two-mode network (firm working on CDM projects) from the CDM project database. Following Ashraf et al. (2014), we transformed two-mode affiliation network (firms x project) into one-mode adjacency matrices (firms x firms). Using these matrices, we computed network constraint as a proxy of network embeddedness. This variable measures the degree to which partners of a focal firm are connected with each other

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<sup>5</sup> KLD (Kinder, Lydenberg and Domini) is an independent ratings service which assesses firm performance across a range of social and environmental dimensions related to stakeholder concerns.

(Ashraf et al., 2014). The higher values indicate more embeddedness in closed network. We used UCINET 6 (Borgatti, Everett, & Freeman, 2002) to compute this measure.

If a firm in a developing country invests in renewable energy technology to benefit from the carbon-offset credit revenues that such an investment can generate (Ashraf et al., 2014), a drop in the carbon price may increase apprehension and uncertainty about the viability of recouping the investment, at least in the short-term. The carbon price in the market signals whether and how much the market will reward the effort of firms to perform sustainably by investing in clean technologies. We therefore took the carbon prices of emission rights as a proxy for *market incentives*. Following Ashraf et al. (2014), we took an average of the spot prices of European emission allowances, that is, the base price used for the CDM market, for the observation years 2007 to 2009. Data was obtained from Bluenext –European Emissions Exchange.

We also controlled for the effects of a firm's *social status*, and measured this variable by computing eigenvector centrality of focal firms following Mathis (2007), using UCINET (Borgatti et al., 2002). The eigenvector centrality gives higher scores to those firms that are connected with more central actors. Moreover, we also controlled for *normative pressure* - the influence of consultants and auditors in the carbon market (Kolk & Mulder, 2011) on the clean technology strategy of firms. These intermediaries act as important actors to affect the norms in an institutional field. We measured this variable by computing the ratio of professional auditing and consultancy firms with whom focal firms were working in a given year. For this purpose, we first counted the number of professional intermediaries of focal firms and divided it by the total number of CDM projects of focal firms. We also controlled for the effects of *scale of investments* (by computing the



proportion of a firm's large-scale projects divided by the total number of projects) on the firm's clean technology strategy. In addition, *firm age* was used to control for the effect of new capital resources and experience in business, and was computed by deducting firm founding year from the year under observation. Moreover, we computed two variables: *network size* and *experience* of firms in the CDM market and used these variables as instruments to check the robustness of our models to potential endogeneity problems. Network size was computed using UCINET 6 (Borgatti et al., 2002) by counting the number of focal firm project partners in a given year. Experience of firms in the CDM market was measured by computing the ratio of their registered CDM projects (total number of registered projects divided by total number of conceived, under-process, or rejected projects).

#### **4. Model estimation & results**

Our dependent variable – adoption of clean technologies<sup>6</sup> - contained the values of 0 or 1, therefore we estimated the model with probit regression (Papke & Wooldridge, 2008). Furthermore, we standardized the variables so that coefficients could be compared. We estimated models stepwise: we first introduced control variables, followed by main predictors, and interaction terms. Table 2 reports the descriptive statistics and correlations between the variables, and Table 3 shows the results. Table 2 shows significant correlations between some variables, however, we did

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<sup>6</sup>The dependent variable was a proportion, however, there were only 15 observations that lay between 0 and 1. We thus dropped these observations to avoid bias in the estimation.

not find the issue of multi-collinearity as variance inflation factors (VIF) for all the variables were found to be below the tolerance level of 10 (Ashraf et al., 2014).

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Insert Tables 2 & 3 about here  
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Compared to the base model 1 (AIC=755.32; *pseudo*  $R^2=0.137$ ;  $p<0.01$ ), the fitness of the models improves when we introduce main predictors, with the exception of model 2 (AIC=757.31; *pseudo*  $R^2=0.137$ ;  $p<0.01$ ). The final model 5, with all the main predictors and interaction effect, is the optimal model (AIC=624.01; *pseudo*  $R^2=0.165$ ;  $p<0.01$ ).

The results (see model 2, Table 3) show that the probability of adopting clean technology decreases when firm slack resources are high ( $\beta= -0.01$ ,  $p > 0.10$ ). The negative sign of the coefficient contradicts our hypothesis 1, however the effect is not found to be statistically significant. The results (see model 3, Table 3) also show the positive, and statistically significant, effect of network embeddedness ( $\beta= 0.189$ ,  $p < 0.05$ ) supporting hypothesis 2. We also find that market incentives (see model 4, Table 3) negatively affect the probability of adopting clean technology ( $\beta= -0.122$ ,  $p < 0.1$ ), contradicting hypothesis 3a.

The results show that, when market incentives are low, firms that are more embedded in closed networks (see model 5, Table 3) have a higher probability of adopting a clean technology strategy ( $\beta= -0.210$ ,  $p < 0.01$ ). This confirms hypothesis 3b, that is, the lower the market incentives, the more likely it is that firms will use their relational network resources, and consequently the higher the probability that firms will reduce emissions through renewable energy technologies. This is further confirmed through interaction plot (refer to Figure 1), which shows that firm network

embeddedness increases the probability of adopting clean technology when market incentives are low.

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Insert Figure 1 about here  
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The final model 5 shows that a firm's social status ( $\beta= 0.164, p < 0.1$ ) is also a significant predictor of its clean technology strategy.

To confirm that results are robust to potential endogeneity that may arise due to correlations of *clean technology strategy* and *network embeddedness* with the error term, we estimated models with instrument variable probit regression. For this purpose, we used two instruments – firm's experience in the CDM market, and network size. The validity of instruments were confirmed through Amemiya-Lee-Newey over-identification test ( $\chi^2 = 0.499, p > 0.1$ ), and Wald tests ( $\chi^2 = 1.71, p > 0.1$ ) of weak instruments<sup>7</sup>. The results of Wald test of exogeneity ( $\chi^2 = 0.38, p > 0.1$ ) showed that *network embeddedness* is not endogenous. Furthermore, to rule out the possibility of reverse causality, that is, firm's climate change strategy may affect its networks i.e. network embeddedness, and social status, we followed Ashraf et al. (2014) and ran Granger causality tests. The results show that firm clean technology strategy does not granger cause network embeddedness ( $\chi^2 = 2.07, p > 0.1$ ), or social status ( $\chi^2 = 0.01, p > 0.1$ ).

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<sup>7</sup>The tests are available through *overid* and *weakiv* functions in STATA

## 5. Discussion & conclusion

Our paper contributes to, and extends, the contingent (natural) resource based view of the firm by cross-fertilizing it with the relational view to explain the adoption of clean technology strategy. We argue that although the contingent resource based view is a dominant paradigm to explain firm environmental strategy (Walls, Phan, & Berrone, 2011), its assumption is that value-creating resources are owned and controlled by the focal firm (Amit & Schoemaker, 1993). While the contingent (natural) resource-based view (Aragón-Correa & Sharma, 2003) takes into consideration external factors in the business environment that are likely to inhibit the adoption of a clean technology strategy, the influence of these factors on a firm's network structure, and the consequences for firm behaviour, is not explicated fully. The relational view of the firm (Dyer and Singh, 1998), on the other hand, takes the effect of a firm's relational network into account. However, the relational view of the firm alone also does not adequately capture all of the underlying mechanisms and moderating conditions that can affect firm environmental strategy. For example, its focus is not on the consequences of resources that firms own *a priori*. By extending the contingent resource based view and combining it with the relational view (Dyer & Singh, 1998), we offer more clarity to explicate the antecedents of clean technology strategy than either theoretical view can offer independently.

The results show that a firm's relational network structure influences its climate change strategy to reduce emissions through renewable energy or clean technologies, particularly when market incentives are low. Contrary to one of the hypotheses and the existing literature (Chih, Chih, & Chen, 2010), the results of our paper suggest a negative relationship between a firm's slack

resources and its clean technology strategy. However, this effect is not found to be statistically significant but indicates that firm-owned financial resources are not sufficient to explain adoption of clean technology in developing country firms.

Our study also provides useful insights into whether market incentives influence a firm's strategy to invest in clean technologies. In the carbon-offset market context, lower market incentives increase uncertainty about the viability of investments. Uncertainty in the carbon market has also been argued to impede investment in clean technologies (Jeswani et al., 2008). In contradiction to this and our hypothesis, we find that higher market incentives decrease the probability of adopting a clean technology strategy. We conjecture that this happens because higher market incentives influence firm strategy in the carbon-offset market to reap financial rewards in the short-term through quick fixes, instead of investing in risky and capital-intensive clean technologies (Slawinski et al., 2017). This finding is also consistent with previous research in the context of HFC-23 emissions under the CDM, which shows that firms actively respond to CDM rules in order to benefit from high carbon revenues at the lowest cost (Schneider, 2011). Thus our study is in line with the literature that highlights concerns about the CDM's ability to promote sustainable development (Olsen, 2007). These concerns now feature in debates about new market mechanisms proposed under Article 6 of the Paris Agreement (Schneider & La Hoz Theuer, 2018).

We also find that, in the case of low market incentives, which increase business uncertainty in the carbon market, firms can benefit from their closed network and can potentially gain a competitive advantage by adopting a proactive strategy (Aragón-Correa & Sharma, 2003). We thus

refine current understanding on the impact of market incentives on firm clean technology strategy by focusing on the benefit of networks.

Notwithstanding the normative concerns about the carbon-offset market as an effective policy response, the literature often overlooks an important point. That is, energy intensive practices are hard to change, and need a sufficient mass of actors, institutions and an incentive mechanism to correct the market anomaly of externalizing the social cost. Through this paper, we offer a different perspective about the efficacy of carbon markets in bringing about a positive change in firm's behaviour in terms of shifting to sustainable sources of energy, which in itself could be considered a major shift in the way firms operate (Klein, 2014; Geels, 2010).

Our study has important implications for policy makers. Market incentives are currently a critical area of concern. Policy makers consider that a high carbon price provides a positive incentive for long-term investment in low carbon and clean technologies. It has been estimated that carbon should be priced in the region of \$40 - \$80/ tonne in order to achieve the temperature goal set by the Paris Agreement (World Bank Group, 2018). However, slow demand and low carbon prices on the EU market is predicted to continue to 2020 (Redmond & Convery, 2015). Our research shows market incentives alone may not be the answer. We find that even where market incentives are relatively low, those firms embedded in a closed network are more likely to adopt clean technology. Thus, in order to stimulate adoption of low carbon technologies in the current environment of the carbon market, we recommend that policy makers focus on initiatives and programmes to facilitate partnerships between actors on the carbon market as well as creating opportunities for knowledge sharing and learning amongst networks of companies. Likewise,

where capital grants or other incentives to develop low carbon or clean technologies are available, these should also be offered to networks of firms rather than being confined to individual organizations.

Our work also provides interesting avenues for future research. As discussed, our results are consistent with the view that networks are important for adoption and diffusion of innovation since they allow information and knowledge to be exchanged across firm boundaries (Robertson, Swan, & Newell, 1996). While in this paper we have concentrated on the role of firm network embeddedness, it would also be interesting to explore how the nature of ties between network partners may be influential in this process. For example, less formal networks such as collaborations with universities or professional associations may also be important for clean technology diffusion in this context (Swan & Newell, 1995). Similarly, the nature of ties between actors may be influential. ‘Weak ties’ among different social groups have been argued to be important for the diffusion of new ideas (Granovetter, 1983). At the level of the firm, this would suggest that more distant or informal contact with other organizations, perhaps in different industry sectors, may also be important for the diffusion of new ideas or new technologies (Robertson et al., 1996). These areas may provide interesting opportunities to advance research in this area.

The study has some limitations that may be addressed in future research. The slack resources of firms may signal possession of idiosyncratic resources, however, we could not account for the effects of complementary resources and capabilities of firms due to unavailability of such information. Notably, in our study we focus on a particular form of financial slack, ‘return on assets’; however other dimensions of financial slack were not explored due to lack of information

availability. The adoption of clean technologies by firms in the face of the increasing urgency of the climate change problem is painfully slow, and while our research is an early attempt to understand the antecedents of a clean technology strategy of firms in a developing country context, there is much more to do in this area. Firstly, our panel data was small and not contemporary; but as technology continues to evolve with renewable energy technology becoming more cost effective, it would be interesting to consider, using a larger dataset, whether this technological evolution is accompanied by greater adoption of clean technology by companies. Secondly, we did not compare and contrast antecedents of clean technology strategy of developing country firms with those of developed countries. Such a comparison, in future research, would clarify the differences between firm strategies in different institutional contexts. Finally, in terms of market incentives, we considered the role of carbon prices. However, it may also be interesting to consider the consequences of changes in the price of fossil fuels or energy generated thereof, and the effects of government subsidies and tax-rebates on firm's clean technology strategy.



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**Table 1: Sample Statistics**

Total number of firms in the sample	342
Number of industries firms belong to:	119
% of major industries in the sample	
Electric Services	19.76
Cement, Hydraulic	12.09
Chemicals	3.54
% of industry with highest number of- renewable energy projects	
Electric Services	36.84
Number of countries firms belong to:	33
% of majority in the sample	
India	36.36
China	35.48
Brazil	3.52
% of countries with highest number of renewable energy projects	
India	42.11
China	29.82

**Table 2: Correlations and descriptive statistics**

Variables	ean	.D.	in.	ax.										
Adoption of clean technologies	.23	.42												
Market incentives	.01	.54	.02	4.25	0.10**	-								
Network embeddedness	.01	.22	.1	.218	.06 <sup>†</sup>	.03								
Social status	.11	.46		.03	.11**	0.01	.05							
Slack resources	.01	.49	78.61	1.3	0.02	.04	0.19**	.01						
Normative pressure	.41	.48			.15**	.23**	0.13**	0.05 <sup>†</sup>	.29**					
Scale of investments	.43	.49			.08**	.24*	.08*	.02	.11**	.38**				
Firm age	5.84	5.24		55	0.06 <sup>†</sup>	.01	.04	0.07*	.07*	.03	0.004			
Firm CDM experience	.03	.15			.01	.04*	.10*	.02	0.06 <sup>†</sup>	0.13**	.08**	.05 <sup>†</sup>		
Network size	.65	.17		2	.004	.08*	0.77**	.03	.12**	.13**	.12**	0.02	0.03	

\*\* p<0.01, \* p<0.05, <sup>†</sup>p<0.10

**Table 3: Results of Probit Regression Predicting the Adoption of Clean Technologies**

<b>Variables</b>	<b>Model 1</b>	<b>Model 2</b>	<b>Model 3</b>	<b>Model4</b>	<b>Model 5</b>
Slack resources		-0.01 (0.07)			-0.056 (0.081)
Network embeddedness			0.189** (0.093)		0.287*** (0.108)
Market incentives				-0.122* (0.063)	-0.345*** (0.073)
Network embeddedness x Market incentives					-0.210*** (0.069)
Normative pressure	0.259*** (0.076)	0.260*** (0.077)	-0.012 (0.086)	0.287*** (0.081)	0.005 (0.091)
Scale of investment	0.202** (0.086)	0.202** (0.086)	-0.088 (0.097)	0.225** (0.089)	-0.094 (0.101)
Firm age	-0.107 (0.113)	-0.106 (0.112)	-0.118 (0.117)	-0.100 (0.113)	-0.090 (0.120)
Social status	0.293*** (0.107)	0.293*** (0.107)	0.197** (0.090)	0.293*** (0.108)	0.164* (0.092)
Constant	-1.101 (0.840)	-1.098 (0.841)	-0.547 (0.846)	-1.043 (0.858)	-0.177 (0.876)
Pseudo R2	0.137	0.137	0.114	0.142	0.165
AIC	755.324	757.310	647.409	753.620	624.013
Observations	611	611	457	611	457

Robust standard errors in parentheses. Industry and country dummies are included in the models but their coefficients are not reported.

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

**Figure 1: Effect of market incentives on the relationship between firm's network embeddedness and adoption of clean technologies**

