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Abstract

This paper examines the determinants of credit allocation to renewable energy firms in developing and transition countries. Using a simple endogenous growth model, we show that the development of the renewable energy sector, i.e. the diversification of renewable energy resources used in primary energy production, depends on the quality of financial intermediation, debtor information costs to banks, and financing needs of renewable energy firms. Policies should aim at increasing financial sector performance through better institutional frameworks and improving financing conditions for new energy firms. The empirical analysis confirms the positive effect of financial intermediary development on the renewable energy sector.

Keywords: Financial intermediation, banks, renewable energy, economic growth
JEL classification: Q42, G10, O41

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1 Introduction

Achieving a diversified and sustainable energy supply for future generations is one of the major challenges for today's policymakers. But financing the necessary energy projects is proving a serious obstacle to this goal. Over the next twenty-five years, global energy demand is projected to grow by nearly 60 percent; more than two thirds of the increased demand will come from developing and transition countries. Energy demand will continue to be covered mainly by conventional fossil fuels, such as coal, oil, and natural gas, with over two thirds of the energy-related pollution increase coming from the developing world (IEA, 2005). Meanwhile, many estimates predict that oil and possibly natural gas production will plateau around the same time, casting doubt on future energy security.[1] Hence, achieving a sustainable energy supply requires diversifying energy sources and changing the current dependence on non-renewable and polluting hydrocarbon fuels.

However, energy projects generally demand high levels of financing, which producers in less developed economies can rarely cover on their own; but obtaining sufficient investment to pursue energy diversification faces a number of obstacles (World Bank, 1999; IEA, 2003). More precisely, the financing for renewable energy technologies (RETs) is closely connected to the development of the financial sector:[2] on the one hand, energy sector privatisation and liberalisation during the course of the 1990s have increased the contribution of smaller private power projects, and at the same time induced a shift in external financing from the local government and multilateral institutions to private investors (Babbar and Schuster, 1998). On the other hand, renewable energy (RE) projects have very high start-up costs relative to the expected monetary returns, and very lengthy payback periods; they therefore typically require long-term maturity loans (UNEP FI, 2004; Sonntag-O'Brien and Usher, 2004b).

Accordingly, the problem of financing RE projects is twofold: first, the availability of the long-term loans needed by RET firms is positively linked to the development of the banking system (Demirgüç-Kunt and Maksimovic, 1999). As a consequence, RE projects in less developed countries are at a particular disadvantage.[3] Second, RET firms firms have limited access to financing because RE projects compete against fossil fuel projects, which have a longer track record, relatively lower up-front costs, shorter lead times, and often favourable

[1] The U.S. Energy Information Administration (EIA, 2000) alone has published several different scenarios, with global oil production peaking between 2021 and 2112.

[2] Another important issue regards the institutional framework: as previous literature has pointed out, limited financing of RETs derives both from the lack of a specific policy design, and/or crowding-out effects from government policies favouring investment in fossil fuel projects (Churchill and Saunders, 1989; Head, 2000; World Bank, 2002; Sonntag-O'Brien and Usher, 2004b; UNEP FI, 2004). Institutional shortcomings also contribute to the often limited consideration by potential investors of the positive environmental externalities of RETs in project development costs. In general, the perception that energy sustainability is not a top priority for policymakers further lowers investors' willingness to finance projects where the foreseeable rewards are already relatively low and long in the coming.

[3] In less developed economies, the banking sector is the major source of external financing (Tadesse, 2002; Carlin and Mayer, 2003; and Beck et al., 2004a), and access to bank credit is a serious problem especially for small- and medium-sized companies (Beck et al., 2004b).

political treatment (Churchill and Saunders, 1989; Head, 2000; World Bank, 2002; and Sonntag-O'Brien and Usher, 2004b).

It is worth noting that in both cases, underinvestment in RET firms can be interpreted in terms of imperfect information between firms and financiers: projects aimed at developing new technologies bear, almost by definition, greater information costs to investors, which are more easily borne by a highly developed financial sector. Where the latter is not given, the result may well be a market distortion in favour of less risky investments, such as fossil fuel projects and large-sized enterprises. This is consistent with the view that the development of the domestic financial sectors is the crucial factor in meeting the booming energy demand in less developed economies (Ishiguro and Akiyama, 1995; World Bank, 2003).[4]

Following this line of reasoning, the paper presents a multi-sector endogenous growth model of the expanding-varieties type (following Gries et al., 2004; and Romer, 1990), which explains the influence of financial intermediaries on the development of RETs in developing and transition countries. The focus is on the development of financial intermediaries—and especially the banking sector and banks' role as evaluators of potential debtors—as a driving force in the introduction of RETs in these countries. We assume imperfect information between RE entrepreneurs and financiers, and show that high information costs to determine creditworthy investment projects, and distortions in the banking sector, have a negative impact on the expansion of the RE sector. Greater RE development and economic growth in the model come from better financial intermediation and lower information costs to banks, as well as lower external financing needs for RE entrepreneurs. Policies should therefore aim at improving financial sector performance in general and financing conditions for RE firms in particular, in order to foster the development of a diversified and sustainable energy sector.

These theoretical findings are tested empirically in a series of panel data regressions for 118 non-OECD countries. The empirical results are fairly encouraging: they confirm the positive effect of financial sector and particularly banking sector development, as well as of power sector reforms, on the use of RETs in developing and transition countries—especially the newer technologies such as wind, solar, geothermal and biomass.

The paper is organised as follows. Section (2) contains the description of the model and the resulting steady-state equilibrium; policy implications are discussed in section (3) and the empirical results given in section (4); while section (5) concludes.

[4]The notion that commercial financing plays an important role in RET expansion in developing countries is empirically confirmed by a number of case studies, for example on the experiences in Bangladesh and Sri Lanka.

2 The model

The approach is based on a simple general equilibrium model of endogenous growth with three sectors: final and primary energy production, and the banking sector. The focus is on the development of the renewable energy (RE) sector in transition and developing economies. Experience in these countries shows that renewable energy technologies (RETs) have typically been adopted from developed countries and not been the result of domestic R&D. The model therefore considers only the expansion of renewable energy resources and firms using already-developed RETs and does not include an R&D sector.

2.1 Final energy provision

We assume that there are N primary renewable energy producers in a given country, each supplying energy derived from a different RE resource R_i, e.g. hydropower, wind, geothermal, photovoltaic and solar thermal, biomass, etc., to the final energy producer. Final energy is produced by means of labour and primary RE resources R_i according to the following extended Cobb-Douglas production function (Romer, 1990; Gries et al., 2004):

$$Y = L^{1-\alpha} \sum_{i=1}^{N} R_i^{\alpha}, \tag{1}$$

where $0 < \alpha < 1$. Since the production function is homogeneous of degree one, there will be constant returns to scale of all inputs taken together.[5] Following the basic idea of the expanding-varieties model, growth is driven by an expansion in N (Barro and Sala-i-Martin, 2004), i.e. a diversification in the primary renewable energy sources. The latter is interpreted as beneficial for the sustainable development of the energy sector: a larger number of RE resources in primary energy production increases the share of RETs in a country's energy supply, and by implication diminishes the dependence on existing primary energy resources used in energy production.

The final energy production sector behaves like a single competitive firm, which maximises profits according to

$$\pi_Y = Y - wL - \sum_{i=1}^{N} P_i R_i, \tag{2}$$

with P_i denoting the price of primary resource R_i and w the wage rate. This implies a demand for primary RE resources given by

[5]The formulation used here also implies that the different types of primary renewable energy in a country are not perfect substitutes but have additively separate effects on a country's energy supply. In a particular case, a new type of primary renewable energy i may substitute for an existing one i', reducing its marginal productivity; but in finite time, the overall independence of marginal product will hold, following Barro and Sala-i-Martin (2004).

$$R_i = L\Big(\frac{\alpha}{P_i}\Big)^{\frac{1}{1-\alpha}}. \tag{3}$$

2.2 Realisation of primary RE production projects

Primary RE production is relatively capital-intensive. Planning and implementing a new energy project, regardless of the type of resource used, is a very costly enterprise. And because of the additional costs facing RETs—e.g. long lead times, low levels of regulatory and financial support, and relatively high production costs in a fledgling industry where economies of scale and learning effects have only recently set in—renewable energy entrepreneurs in less developed economies are especially reliant on outside financing, as their own wealth is unlikely to be sufficient to cover their investment needs.[6]

In the model, the RE entrepreneur has own wealth of W, which by assumption is less than 1. He must therefore obtain $1 - W = Z$ units of financing from an outside creditor in order to undertake a new energy project. If the creditor decides to award the loan necessary to finance the project, he will charge periodic interest payments Zr_l on the credit.

The main source of finance for entrepreneurs in developing and transition countries is the banking sector. We exclude the possibility of Ponzi schemes by assuming that firms revolve loans infinitely and service no more than the interest payments (Gries et al., 2004). With r_d denoting the bank deposit rate, the present discounted value of the entrepreneur's setup costs is $V_s(t) = \int_t^\infty Zr_l e^{-\int_t^v r_d(s)ds}$. r_d is constant in a steady-state equilibrium, and the setup costs simplify to

$$V_s = Z\frac{r_l}{r_d}. \tag{4}$$

After obtaining the initial project credit from the financier, profit flows of primary energy producers may continue to be affected by the quality of the banks' financial intermediation. The level of banking sector distortion is captured by τ, which enters the profit stream as an indirect "tax" on banking services provided to the entrepreneur once he has been granted the initial loan. The "tax" rate τ depends on the legal and institutional environment and includes factors which influence banks' lending ability such as currency taxes, as well as accounting standards and the power of banks to draw up contracts.[7]

[6] Whether we consider a new investment project by an established firm or the start-up of a new energy firm, financing needs in the energy sector are still likely to surpass own wealth. For a study of the financing patterns of the energy sector in less developed countries, see World Bank (1999).

[7] King and Levine (1993b) introduced a similar financial sector "tax" caused by market distortions in their model. For empirical studies of indirect financial sector taxes, see Chamley and Honohan (1990) and Giovannini and de Melo (1993). For more on institutions and financial intermediation, see La Porta et al. (1997), Demirgüç-Kunt and Maksimovic (1998), Levine et al. (2000), and Beck et al. (2004a).

In addition, the RE producer will have to pay costs of δ on each unit of energy resource he uses. δ includes periodic costs of primary energy production, e.g. maintenance costs for wind mills or photovoltaic panels. The primary RE production sector cannot be described by a single firm; instead, there is a distinct firm i which produces energy with each RE resource R_i. Once the primary energy producer has secured the financing of his project, he can supply his output to the final energy producer. In this form of monopolistic competition between primary RE producers, the present discounted value of the infinite stream of returns on the initial investment is given by $V_r(t) = \int_t^\infty \big((1-\tau)P_i - \delta\big)R_i e^{-\int_t^v r_d(s)ds}$. In the steady state, the interest rate r_d is constant and the net present value of returns is given by

$$V_r = \frac{1}{r_d} R_i\big((1-\tau)P_i - \delta\big). \tag{5}$$

The primary energy producer takes the demand curve for primary RE by the final energy provider (3) as given when choosing the profit-maximising price to set. Profit maximisation gives the optimal primary resource price P, which holds for all RE resource types,

$$P = \frac{\delta}{\alpha}\frac{1}{(1-\tau)}. \tag{6}$$

Using the optimal price P (6) and equation (3), and substituting them in (5) yields a net present value of the RE producer of

$$V_r = \frac{1}{r_d} L\left(\frac{1-\alpha}{\alpha}\right)\left(\frac{\alpha^2(1-\tau)}{\delta^\alpha}\right)^{\frac{1}{1-\alpha}}. \tag{7}$$

Primary energy producers compete for bank credits to realise their projects; setup costs must therefore equal the net present value of profits $V_s = V_r$. This leads to a loan demand by the RE producers of

$$r_l = \frac{L}{Z}\left(\frac{1-\alpha}{\alpha}\right)\left(\frac{\alpha^2(1-\tau)}{\delta^\alpha}\right)^{\frac{1}{1-\alpha}}. \tag{8}$$

Equation (8) gives the equilibrium interest on loan payments that the RE producers will be willing to pay the bank.

2.3 The banking sector

Banks keep deposits D and make interest payments to their depositors at rate r_d, and they allocate credits Q at the loan rate r_l. Of potential RE entrepreneurs applying for a loan, only a fraction ϕ will actually be creditworthy. However, there is a critical situation of imperfect information between the possible debtor

and the investor: the financier cannot directly observe the quality of the investment project. Instead, he has to evaluate the RET project's potential at cost f before deciding on credit allocation. The reasoning is that although the entrepreneurs may observe their own potential costlessly, they cannot evaluate and credibly communicate it to the financial intermediators.[8] We assume that the financing constraints of RE entrepreneurs and information costs to financiers are similar across different RETs.

Banks are faced with a balance-sheet constraint which requires that total assets—credits Q plus reserve holdings RD—equal total liabilities, i.e. deposits D:

$$Q + RD = D. \tag{9}$$

In this model, we concentrate on the market distortions affecting the financial intermediation between banks and debtors, and assume that *interbank* frictions are negligible and reserve holdings unnecessary. This means that $RD = 0$ and that total credits Q must equal total deposits D at all times. Bank profits are thus given by

$$\pi_B = \left(r_l - \frac{f}{\phi}\right) Q - r_d Q. \tag{10}$$

Profit maximisation yields the bank loan supply of

$$r_l = r_d + \frac{f}{\phi}. \tag{11}$$

The result corresponds to a situation with zero profits. Credit market equilibrium is given by $Q = ZN$.

2.4 Households

The model uses a standard description of consumer preferences. The representative household maximises intertemporal utility according to

$$U = \int_o^\infty \frac{C^{1-\sigma} - 1}{1 - \sigma} e^{-\rho t} dt \qquad \text{for } \sigma \in [0, \infty). \tag{12}$$

ρ denotes the rate of time preference, and $1/\sigma$ indicates the intertemporal elasticity of substitution. The households' income will come from interest on deposits and wages and can be spent on consumption or savings (further deposits), giving the following budget constraint

[8] See King and Levine (1993b), and Fazzari et al. (1988) for more on the importance of imperfect information in new debt provision.

$$Dr_d + wL = C + s = C + \dot{D}. \tag{13}$$

The first-order conditions imply the familiar Keynes-Ramsey rule:

$$\gamma_C = \frac{r_d - \rho}{\sigma}, \tag{14}$$

where $\gamma_C = \dot{C}/C$ is the equilibrium growth rate of consumption. In the steady state, consumption and output grow at the same rate $\gamma_C = \gamma_Y = \gamma$, and $r_d = \gamma\,\sigma + \rho$.

2.5 Solution for the steady state

Combining the primary RE producers' loan demand (8) with the banks' optimal loan supply (11) and the Keynes-Ramsey rule (14) gives us the solution to the model

$$\gamma = \frac{1}{\sigma}\left(\frac{L}{Z}\Big(\frac{1-\alpha}{\alpha}\Big)\Big(\frac{\alpha^2(1-\tau)}{\delta^\alpha}\Big)^{\frac{1}{1-\alpha}} - \rho - \frac{f}{\phi}\right). \tag{15}$$

This steady-state growth rate applies to the number of primary RE firms N, as well as output Y and consumption C.

The most interesting aspects of the solution regard the signs of the terms involving the banking and RE sectors. Banking sector distortions, captured by τ, will negatively affect growth, as less efficient financial intermediaries channel part of firms' profits away from growth-enhancing activities. Also, a higher proportion of creditworthy investment projects ϕ will have a positive effect not only on the RE sector's growth, but on the growth of the economy as a whole. We further see that higher information costs f to the financier evaluating a potential creditor will result in lower growth rates.

A higher dependence of the RE producer on external financing for a project (a larger credit Z) is associated with a lower growth rate.[9] Similarly, higher resource costs to the primary RE producer δ will also result in less growth in the RE sector and the economy overall. Finally, the model shows that a greater willingness to save by the households—lower ρ and σ—raises the growth rate.

Possible extensions regard the inclusion of positive production externalities, e.g. better environmental quality and lower economic and social costs due to pollution. Through specific policies such as production subsidies and guaranteed feed-in prices, these benefits can be internalised to lower the production costs per unit of RE δ. Formally, this can be represented as $\delta = \delta_0 - \epsilon$, where δ is the net total periodic production cost per unit of primary RE resource.

[9] The higher the credit need of an entrepreneur, the lower the interest rate on the loan must be for him to be able to undertake the project, according to equation (8). Banks will be less willing to give a credit, depressing the overall growth rate.

δ_0 includes the actual production cost such as equipment maintenance, while ϵ is the per-unit value of production externalities. It is easy to see that the inclusion of these externalities in the equation would have a positive impact on RE sector development.

3 Policy implications for RE sector development

The model's findings have several implications for the development of the renewable energy sector. We will discuss two main issues involving the banking sector, and other important points regarding RE production costs and the external financing needs.

First, the cost τ is associated with inefficiencies in the provision of banks' services. Banking sector distortions increase direct and indirect costs to the debtors: examples of these distortions include narrow restrictions on banks' operations and services to clients (Demirgüç-Kunt and Maksimovic, 1998). One may argue that this "tax" applies equally to all energy firms operating in a given country, and not only to the RE producers represented in the model. However, energy firms in the conventional fossil fuel industry tend to be older and more established than RET firms, and may have greater means of using legal loopholes and institutional weaknesses to their advantage. Especially in regions where the economy depends on the income from the hydrocarbon extraction, refining and transportation industries, fossil fuel companies often have privileged access to local financing. Government policy should aim at providing a clear legal and institutional framework to create a more efficient banking sector, and at enforcing the rules which are put in place.

The second issue regards the potential creditor evaluation costs to banks f: the message is that better information on the available renewable energy technologies will foster the sector's development, i.e. an increase in N. From energy sector surveys and firms' own accounts, it appears that renewable energy projects are at a particular disadvantage because of the short track record of the new energy technologies, high up-front costs, and relatively low returns spread out over long periods (Sonntag-O'Brien and Usher, 2004a,b). This implies higher information costs to the financier in order to properly assess the creditworthiness of the RE investment project. In addition, government policies favouring fossil energy producers, such as guarantees and special fiscal incentives, make the evaluation of a RET project *vis-à-vis* a fossil fuel project even less attractive and more costly for the financier.

The potential investors' evaluation costs can be reduced through public policy, e.g. by raising awareness and providing better information on new technologies and the risks and experiences connected with them. These costs can also be lowered more indirectly by eliminating tax breaks and other incentives granted to fossil fuel producers, or by setting up similar incentives for funding RE. The latter policy option would have a more direct positive effect on the fraction of creditworthy RE entrepreneurs ϕ. There is also increasing experience of shared

RE project funding through public-private partnerships (PPPs), which can allow a cash-strapped government to mobilise complementary financing sources by mixing its experience in public-sector infrastructure and the reduced risk of partial governmental guarantees with private-sector commercial and financial experience.[10]

Bank concentration reduces financing opportunities in countries with less developed economies and institutions (Beck, 2003), making banking sector competition another policy goal for better-functioning credit allocation, which would affect both the distortional tax τ and the bank information costs f. An interesting alternative to traditional commercial banking, which also contributes to greater competition in financial intermediation, is venture capitalism (Rajan and Zingales, 2001). Venture capitalism has emerged as an important source of start-up investment finance, which could mitigate some of the difficulties involved with financing RE firms. However, the lack of well-developed legal frameworks and the generally greater political risk in developing and transition countries are two factors which reduce the investment attractiveness for venture capitalists, who rely on clear and enforceable contract laws and accounting standards to exercise their organisational rights and profit guarantees and, finally, their exit strategy.[11] The better institutions mentioned earlier could not only help increase competition in the traditional banking sector, but also attract new types of relationship-based financial intermediaries able to optimally evaluate credit potential.

Another policy implication is given by the primary resource-specific costs δ: possibilities for intervention in this area are numerous. Based on the premise that different types of energy resources create different types of externalities, primary resource-specific costs could vary according to the principle of internalising externalities. The positive effect for RE firms of lower net production costs per unit δ also acts through the higher loan interest rate that they would be willing to pay to lenders (see equation (8)). Benefits of renewable energy use can be priced in, for example by providing direct subsidies to RE firms or guaranteed feed-in costs into the national energy distribution grid for energy produced using new technologies, a system which has been successfully implemented for example in Germany. As economies of scale and learning effects reduce the costs associated with RETs, making them more competitive with fossil fuels, the incentives are gradually phased out.

In addition, a policy targeted at lowering production costs for RE would have an indirect effect on RE firms' access to bank financing. Government subsidies affect financial intermediaries' decisions through implicit or explicit backing of certain firms or sectors, leading in fact to a credit market distortion and more favourable lending terms (Demirgüç-Kunt and Maksimovic, 1999). Accordingly, in the model a subsidy decreasing δ would act as a government guarantee, lowering information costs f for lenders and at the same time in-

[10] An example for a PPP is given by mezzanine funds, i.e. subordinated debt with a risk level somewhere between equity and bank debt.

[11] Whether or not a venture capitalist or even a market-based financial system should be preferred to a bank-based system is beyond the scope of this paper. For more on the debate of bank-based vs. market-based financial intermediation, see Levine and Zervos (1998).

creasing the fraction of creditworthy RE firms ϕ, and therefore pushing down the loan interest rate demanded by banks (see equation (11)).

Finally, public policy can intervene to reduce the external financing Z needed by RE firms, e.g. through grants and public facilities aimed at sharing project development and transaction costs (World Bank, 2002; Matsukawa et al., 2003; Sonntag-O'Brien and Usher, 2004a,b; UNEP, 2004). Governments in transition and developing countries may however not award a high priority to these policies, or simply not have the means to design and implement them. Advice and loans provided by international institutions can and have already been helpful, but risk creating situations of dependency and not being very effective or efficient in the long run.

4 Empirical evidence

The theoretical model presented above predicts that a better-developed financial sector will have a positive impact on the development of the renewable energy sector. The focus in particular has been on the importance of an unrestricted banking sector and of low information costs on RETs for financiers in order to foster the RE sector in transition and developing economies. This section presents an empirical framework to test these effects.

4.1 Method and data description

There has so far been only anecdotal evidence on the role of commercial finance in the development of RE. The lack of a more systematic empirical analysis of the correlation between financial sector and RE development is also due to the data problem regarding the quantification of the RE sector, especially in the developing world. The obstacles begin with the definition of RE in official statistics: traditionally, hydropower—mostly provided by large plants—has delivered the lion's share of renewable energy in countries' energy production mix, with other types of RE—when included—making up for barely a few percent of the overall energy production. Recently however, some environmentalists and policymakers have contended that large hydropower projects should not be viewed as viable contributions to sustainable energy production, as they often cause serious and substantial negative environmental and social externalities.

We consider these issues when testing the importance of financial intermediation for RET development by using two different dependent variables as proxies for RE sector development. The first, *reshare*, measures the overall RE share—including all types of hydro—in net total electricity generation. In a second series of estimations, we take into account the importance of large hydropower in electricity generation and their possible distorting effect on the results[12] by using the non-hydro RE share in net total electricity generation as

[12]Most traditional, large hydro projects in the developing world have been co-financed by

the dependent variable (*geoshare*). This measure includes electricity produced from geothermal, solar, wind, and wood and waste energy resources. The data for both dependent variables is freely available from the U.S. Energy Information Administration (EIA). The covariates include four different indicators of financial sector development, and a vector of control variables, described below.

The data set provides an unbalanced panel for up to 118 non-OECD countries with observations for a maximum of 24 years (1980-2003). We perform generalised least squares (GLS) regressions for the equation

$$Y_{it} = \beta_1 + \beta_2 F_{it} + \beta_3 X_{it} + \omega_{it}, \tag{16}$$

where Y_{it} is the dependent variable (*reshare* or *geoshare*) in country i at time t, F_{it} denotes the financial sector development variable, and X_{it} the vector of control variables.[13] The composite error term ω_{it} consists of the country-specific error component ϵ_i and the combined cross-section and time series error component u_{it}, according to $\omega_{it} = \epsilon_i + u_{it}$.[14]

The financial sector development indicators are not direct measures of banks' efficiency in credit allocation, but rather different proxies for financial intermediary development tested in the literature. The first variable, *privcred*, captures the amount of credit provided by financial institutions to the private sector as a share of GDP. It excludes credits issued by governments and development banks. An unrestricted financial sector can be expected to account for a larger share of lending to the private sector. In fact, this variable has been shown by Levine et al. (2000) to be a reliable measure of financial intermediary development, i.e. the ability of financial institutions to efficiently mobilise and allocate resources to profitable ventures. Earlier versions of the measure were used for example in King and Levine (1993a,b) and Levine and Zervos (1998). We expect *privcred* to correlate positively with the level of development of the RE sector.

The second variable, *commbank*, measures the importance of commercial banks' asset share versus that of the central bank. In more highly developed and open economies, the commercial financial sector handles a greater share of household savings than the central bank. Assuming that the commercial financial sector is more efficient than the public one in allocating credits, *commbank* should positively correlate with RET development. This variable has also been tested several times in the literature, e.g. in King and Levine (1993a,b) and Levine et al. (2000).

The third variable, *findep*, is a general measure of financial sector development commonly known as "financial depth", i.e. liquid liabilities of the financial

multilateral financial institutions (MFIs) and the local governments, with little or no involvement sought of commercial finance (World Bank, 2003). The use of the overall RE share may therefore not only distort the results on the importance of the financial sector for more modern RETs, but in fact reverse them.

[13] Estimations were performed both with 1-year-lags for the financial indicators—as financial sector changes are not expected to have immediate effects—and 4-year-averages for all variables. For a detailed description of the variables and sources, see Appendix B.

[14] See for example Baltagi (2001) or Hsiao (2003) for an extensive discussion of panel data analysis models.

system (generally M2) divided by GDP, which has been widely used in the literature on finance and growth since King and Levine (1993a,b). The present variable is based on the more sophisticated measure developed in Levine et al. (2000). The assumption is that the relative size of the financial intermediary sector is positively correlated with the quantity and quality of the financial services provided, and we would therefore expect a positive influence on the development of RETs.

The fourth and final financial sector variable, *finunder*, takes a different approach, measuring financial *underdevelopment* or *repression* as the ratio of reserve holdings to liquidity. A high reserve ratio is expected to have a negative impact on the amount of assets available for credit allocation and consequently the development of RETs, since "a high coefficient of required reserve for commercial banks will force them to hold a greater amount of non-interest bearing monetary reserves" (Roubini and Sala-i-Martin, 1992, p.25).

Our main control variable *psreform* describes the level of power sector reform in developing and transition countries. It is based on a broad qualitative survey by the World Bank conducted in 1998 (ESMAP, 1999) and takes on values from 0 (least reformed) to 6 (reforms in all relevant areas have been implemented). The evaluation considers measures to create equal market opportunities for all energy resource types and encourage private firms' participation and competition. Hence, *psreform* is a proxy for government energy policies. As discussed in the previous section, the institutional framework is a crucial element of financiers' information costs on RETs (i.e. f in the theoretical model), signalling a government's commitment to levelling the playing field for energy providers and thereby reducing uncertainty about future profitability of a RE project. Since there is no reliable data available on creditor evaluation costs in less developed economies, this crude proxy will have to suffice. We expect a positive impact of power sector reforms on the RE sector, particularly on the share of non-hydro RE.

Several other control variables are included.[15] Official development assistance by multilaterals (*oda*) aims to control for the effect of multilateral donor money, while foreign direct investment (*fdi*) and net domestic investment (*inv*) capture general private investment in a country (*inv* being the more complete measure, including portfolio investments and financial derivatives as well as foreign and domestic capital and equity investment). Further variables include regional and period dummies (for the 4-year average estimations); initial real GDP per capita; and a measure of economic development (*devind*) ranging from 1 to 4 based on the World Bank classification of low, lower middle, middle, and high income countries according to 2003 GNI. Finally, we control for the possible exogenous effects on RE development of the costs of non-renewable energy resource production by including the average annual market price of crude oil. If the price of the most common conventional fuel affects investment in alternative energy sources, we would expect a positive effect of an oil price increase

[15] Unfortunately, there is not enough cross-country data available on RE *potential* to provide a useful control variable. However, we believe that this does not greatly bias our results given the range of RETs considered.

Table 1. Financial development and the share of renewable energy resources in total net electricity generation in non-OECD countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A								
Dep't variable is reshare								
logfindep	−4.43***	−4.36***						
	(0.76)	(0.76)						
logprivcred			−0.87***	−0.85***				
			(0.31)	(0.31)				
logcommbank					−7.45***	−7.52***		
					(1.21)	(1.33)		
logfinunder							1.19***	1.01***
							(0.31)	(0.39)
logfdi	−0.67***	−0.64***			−1.06***	−0.86***		−0.912***
	(0.18)	(0.18)			(0.23)	(0.24)		(0.18)
devind		−9.95***		−8.48**	−8.85**		−10.71**	−9.08**
		(3.63)		(3.98)	(3.73)		(4.22)	(4.25)
eefsudummy		−24.13***	−22.77***	−20.89***		−20.08**	−13.98*	−14.14*
		(-24.13)	(8.16)	(8.14)		(8.86)	(8.26)	(8.33)
oilprice		0.02		0.01		−0.04	0.05	
		(0.04)		(0.04)		(0.04)	(0.04)	
R^2	0.22	0.15	0.12	0.16	0.15	0.19	0.14	0.14
N	1541	1541	1883	1883	1203	1031	2077	1629
Panel B								
Dep't variable is geoshare								
logfindep	0.52***	0.49***						
	(0.17)	(0.17)						
logprivcred			0.22***	0.21**				
			(0.08)	(0.08)				
logcommbank					0.49**	0.42**		
					(0.22)	(0.2)		
logfinunder							−0.13*	−0.13*
							(0.08)	(0.08)
psreform	0.54***	0.54***	0.53***	0.53***	0.44	0.45**	0.53***	0.44**
	(0.18)	(0.20)	(0.18)	(0.20)	(0.27)	(0.2)	(0.18)	(0.19)
logoda					0.27***	0.19***	0.18***	0.19***
					(0.07)	(0.06)	(0.06)	(0.06)
devind						-0.18	−0.21	
						(0.54)	(0.5)	
eefsudummy		−2.47**		−2.44**	−3.15	−2.52**		−2.543***
		(1.02)		(1.02)	(2.15)	(0.99)		(0.97)
oilprice		0.00		0.01		0.01		0.01
		(0.00)		(0.01)		(0.01)		(0.01)
R^2	0.07	0.11	0.09	0.13	0.12	0.13	0.08	0.13
N	1125	1125	1053	1053	1118	1352	1346	1346

Notes: All regressions are random-effects GLS on full sample panel of 118 non-OECD countries from 1980-2003 with 1-year-lags in financial indicators. Regressions were also performed for 4-year average data, which yielded very similar results and are not reported here. Other control variables are not listed as they proved insignificant. Standard errors in parentheses. *, **, *** statistically significant at 10, 5, and 1 percent levels, respectively. Joint significance tests strongly reject hypothesis of no difference between covariates in all estimations. For detailed variable descriptions and sources see Appendix B.

on the share of RE in power production.

4.2 Estimation results

It is of particular interest to observe the sign and statistical validity of the financial sector coefficients β_2 rather than their actual magnitude, given the quality of the data for the RE sector. The aim is to observe whether the development of the RE sector is positively influenced by the financial intermediary sector, and especially by the banking system.

Table 1 reports the results for random-effects regressions on the full sample[16] for RE share (panel A) and non-hydro RE share (panel B). It is apparent that the four financial sector variables are statistically significant when regressed on both measures of RE sector development, and that they are fairly robust to controlling for other effects both regarding their statistical significance and the magnitude of their coefficients. *findep* and *privcred* generally prove more reliable, while *finunder* has the weakest explanatory power, with *commbank* situated in between.

It is however interesting that the signs of the four coefficients are consistently opposite when estimating with *reshare* versus *geoshare* as dependent variables. When considering non-hydro RE share (panel B), the signs correspond to those predicted by the theory, namely that financial sector development has a positive effect on the development of RETs. When hydropower is included in the estimations, the situation changes round completely, confirming the inherent difficulty surmised above in including mostly MFI-financed (large) hydro in the sample. This hypothesis receives further support through the high significance of the economic development indicator *devind* observed in panel A.[17] If it is true that development banks in the past favoured large hydro projects, then we would indeed expect to find a negative relationship between economic development and the overall RE share. The economic development effect loses significance when considering only non-hydro RE (panel B).

Regarding the other variables in table 1, we find a significant and robust positive effect of power sector reforms on the share of non-hydro RE (panel B), confirming the hypothesis that policies aimed at levelling the playing field for all energy types encourage the development of RETs (other than large hydropower projects). For a certain institutional framework in the power sector, the financial development coefficients consistently show the expected signs with a high level of significance.

It is also interesting to note the effect of including regional dummies in the estimations (with Asia and Oceania being the omitted regional dummy). Eastern European and former Soviet Union countries have a consistently lower share of all types of RE, especially of non-hydro RE. This can be explained by the decades of socialist energy policy favoring the use of fossil fuels in electricity generation and energy production in general. The other regional dummies were not statistically significant. Last but not least, the inclusion of oil prices had no significant effect on the magnitude or error margin of the other variables. With one exception, oil prices had the expected positive sign, but proved statistically insignificant in both estimation series. World oil price fluctuations do not appear to have had a noticeable influence on RE development during the time period observed.

In sum, the results of the empirical analysis support the basic hypothesis

[16] Both random-effects and fixed-effects estimations were performed on all variables for the lagged sample and the 4-year averages. As the Hausman test showed no clear advantage of using fixed effects, only random-effects estimation results are shown. See Baltagi (2001) for more details on the Hausman specification test.

[17] Initial real GDP per capita had a similar effect. For simplicity, only the results using the economic development indicator are shown.

from the theoretical model that financial intermediary development encourages the growth of the RE sector, especially when limiting the estimations to non-hydro RETs. The findings are also quite robust to the inclusion of other covariates which could influence RE sector development. But further empirical research is needed to corroborate these results, as they very likely suffer from measurement errors due to the quality of the available RE data.

5 Conclusions

The paper examines the determinants of credit allocation to renewable energy firms in developing and transition countries. It develops a multi-sector endogenous growth model to explain the financing problems of renewable energy (RE) projects in these countries. Growth in the model stems from the diversification of the primary RE production sector, i.e. the use of a more varied range of renewable energy technologies (RETs) in energy production. Energy production today relies on exhaustible and polluting conventional fossil fuels, and a larger share of alternative energy sources in primary energy production would not only have positive environmental effects, but would also bring greater energy security for future generations, as RETs exploit domestic renewable energy resources. Diversification in the use of RETs is hence assumed to be beneficial for a sustainable energy sector.

Energy firms in less developed economies are largely dependent on external financing to realise new projects; in turn, external financing in these countries relies on the banking sector, as stock markets and venture capitalism are not well enough established to provide large-scale funding. However, the underdevelopment of the banking sector, in addition to specific RE-sector problems such as high up-front and information costs and long lead times, hamper the emergence of RE entrepreneurs. The steady-state equilibrium solution yields several results: less banking sector distortion and lower evaluation costs to potential creditors will increase growth rates, while higher external financing needs by the RE firm will lower growth rates.

Several policy recommendations for the emergence of RETs are derived: general banking sector development through creating better legal and institutional frameworks, as well as the more targeted provision of information on new energy technologies. Specific measures aimed at reducing the relative price of RE production through taxes or fixed feed-in prices (to include positive externalities) are also considered, as well as the merit of public-private partnerships to lower project costs for generators and the perceived risk for financiers. In short, there are many ways of levelling the playing field for new energy technologies. The subsidy option should however be a temporary instrument to boost the development of a sustainable energy sector and future energy security. As new energy technologies take off, scale and learning effects will ensure their market success.

The positive effect of financial sector development on the development of

RETs found in the theoretical model is tested empirically. The results are encouraging: all four variables measuring financial intermediary development are significant and have the expected signs. In addition, energy sector reforms also have a significant positive effect. The results are fairly robust to the addition of other control variables—including world oil prices, which appear to have no impact on RE sector development.

The approach is a first attempt at modelling and empirically verifying the financing difficulties facing the renewable energy industry. The availability of quality data on RE development and investment has so far hampered empirical studies in this area; further work is needed to corroborate the results. An interesting extension for future research is the role that financial intermediaries play in the substitution of fossil fuels in favour of RE.

A Appendix

Descriptive statistics of main variables

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
reshare	2497	47.53	34.67	0.01	100
geoshare	2497	1.21	4.08	0	40.18
findep	2726	37.41	24.71	0.00	168.85
privcred	2607	25.55	22.56	0.00	151.77
commbank	3008	74.07	23.68	2.98	136.59
finunder	3069	26.55	128.44	−13.24	5017.639
psreform	115	2.04	2.09	0	6
oilprice	24	22.62	6.46	12.72	35.69

B Appendix

Variables and sources

All data were collected for non-OECD countries (as of 1980—the recent OECD members Czech Republic, Hungary, Korea, Mexico, Poland, and Slovakia were included in the estimations) for the years 1980-2003 (where available).

Variable	Definition	Source
reshare	Share of renewable energies—including hydro, wood and waste, geothermal, solar, and wind—in net total electricity generation	EIA
geoshare	Share of non-hydro renewable energies—including geothermal, wind, solar, and wood and waste—in net total electricity generation	EIA
findep	Financial depth measured by $100^*(0.5^*(M2_i(t) + M2_i(t-1))/GDP(t))$ where $M2$ is liquid liabilities (lines 34+35) and GDP is line 99b	IFS
privcred	Credit by financial institutions to the private sector as share of GDP, measured by $100^*((0.5^*CREDIT(t)+CREDIT(t-1)))/GDP)$ with $CREDIT$ being total private sector credit allocations by deposit money banks and other financial institutions (lines 22d+42d) and GDP line 99b	IFS
commbank	Commercial bank asset share versus central bank, measured by $100^*(DBA(t)/(DBA(t)+CBA(t)))$ where DBA is assets of deposit money banks (lines 22a-d) and CBA is assets of the central bank (lines 12a-d)	IFS
finunder	Financial underdevelopment or repression measured by $100^*(COMM(t)/M2(t))$ where $COMM$ is commercial bank reserves (line 20) and $M2$ is liquid liabilities (lines 34+35)	IFS
oda	Official development assistance and official aid—disbursements by multilaterals	OECD
fdi	Foreign direct investment (line 78bed)	IFS
inv	Net sum investment in economy, including direct investment, portfolio investment, financial derivatives, and other investment (line 78bjd)	IFS
cgdp	Per capita real GDP in 1980	Penn World Tables 6.1
devind	Development indicator based on the World Bank classification of countries by income (2003 GNI) from low (1) to high income (4)	World Bank
psreform	Qualitative power sector reform indicator for 1998, ranging from 0 (no reforms) to 6 (all relevant reforms implemented in all areas)	ESMAP(1999)
oilprice	Crude oil prices measured in USD per barrel, in current dollars, from 1980-2003	British Petroleum

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