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Past as prologue: an innovation-diffusion approach to additionality

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The 'additionality' criterion for the Clean Development Mechanism (CDM) (which is key to ensuring that CDM projects lead to real and additional emission reductions) has been a topic of much analysis and discussion. A number of different approaches, including those based on financial, barrier and market-penetration criteria, have been suggested as a test for additionality. A simple test for additionality is proposed that draws on the framework of the diffusion of innovations, especially the risk profile of adopters of new technologies or innovations. This approach has the potential to streamline the assessment for additionality, although it will require data on the rate of implementation of specific technologies or innovations.

Keywords: CDM; CERs; climate policy; developing countries; innovation; technology transfer

Le critère d' « additionnalité » du mécanisme pour un développement propre (MDP) (essentiel pour assurer que des réductions d'émissions réelles et additionnelles soient issues des projets initiés dans le cadre du MDP) a été un sujet propice à l'analyse et au débat. Nombre de différentes approches, y compris celles fondées sur les critères d'investissement, des barrières et de pénétration du marché, ont été avancées comme tests d'additionnalité. Un test simple est proposé, dans un cadre de diffusion pour l'innovation, s'appuyant en particulier sur le profile de risques des acquéreurs de nouvelles technologies ou d'innovations. Cette approche a le potentiel de rationaliser le test d'additionnalité, tout en nécessitant des données sur le rythme de mise en place de technologies ou innovations spécifiques.

Mots clés: MDP; RECs; politique climatique; pays en développement; innovation; transfert des technologies

1. Introduction

The UNFCCC aims to stabilize atmospheric greenhouse-gas (GHG) concentrations 'at a level that would prevent dangerous anthropogenic interference with the climate system' within a time-frame necessary for natural adaptation of ecosystems to climate change and for economic development to proceed in a sustainable manner. The Kyoto Protocol, the first step in mandating GHG emissions reductions, has set targets for Annex I countries, along with some leeway in how to meet these targets through flexibility mechanisms such as the Clean Development Mechanism (CDM). The goal of the CDM is twofold: to promote (environmentally) clean development in non-Annex I countries by, *inter alia*, enhancing sustainable development through the uptake of clean technologies; and to help Annex I countries meet their Kyoto commitments using Certified Emissions Reductions (CERs) earned through GHG mitigation projects in non-Annex I countries.

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Mathur.pmd 230 11/10/2007, 10:39 AM

A key requirement for any project to be registered as a CDM project is that it 'provides a reduction in emissions by sources, or an enhancement of removals by sinks, that is additional to any that would otherwise occur' (Kyoto Protocol, Article 6(1)(b)), This is generally referred to as the 'additionality' criterion, motivated in large part by the intention that the project-based emissions reductions represented by the CERs in non-Annex I countries (which do not have economy-wide caps on emissions) are real and additional reductions. This is an important issue, since providing CERs to projects that turn out to be 'non-additional' would lead to an increase in global GHG emissions.[1] Determination of the emissions baseline and assessment of additionality, though, have posed major challenges not only for the registration of these projects by the CDM Executive Board (EB), but also for the initiation and development of such project activities.

While emissions reductions from a project activity can be determined once a baseline has been established, assessing the additionality of a project has proven to be more complicated. There is much debate within the CDM community, as well as among analysts and academics, about how to interpret and apply the additionality clause. Therefore, progress on the CDM front requires a practical and consistent definition of additionality.

2. Approaches to additionality

The Kyoto Protocol, as well as the Marrakech Accord, is explicit in requiring CERs to reflect 'emissions additionality'; i.e. a 'CDM project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM project activity'.[2] However, most of the discussions surrounding additionality have been on 'investment additionality', i.e. investments that would not be made in the absence of CER revenue, and on 'project additionality', i.e. projects that would have not happened in the absence of the CDM.

There has been significant discussion, for example, on the kinds of barriers that might prevent such mitigation actions from occurring. Carter (1997) and Beuermann et al. (2000) have proposed qualitative definitions whereby project developers need to describe and show specific barriers for CDM projects that do not exist for business-as-usual (BAU) cases, with the existence of these barriers implying that projects are 'additional', and not yet commercial. Others (such as Baumert, 1999; Meyers, 1999; Greiner and Michaelowa, 2003) have proposed approaches based on specific aspects of project economics as ways to test for the 'additionality' criterion. Recognizing the advantage of quantitative approaches, Greiner and Michaelowa (2003) have suggested assessing financial indicators (such as IRR, NPV, etc.) of proposed projects against threshold benchmarks or reference BAU projects.

The current version of the CDM EB's 'additionality tool',[3] which is used to judge whether a project is additional or not,[4] seems to have drawn on many of the above discussions on barrier and investment analysis. The tool aims to assess the intent of the project developers,[5] requiring them to analyse various financial and technical barriers for implementing the project without CDM. Rather than just determining whether the project provides emission reductions below a defined baseline, a proposal must also demonstrate that it is either financially unattractive without CDM revenue (investment analysis), or faces barriers which prevent its implementation (barrier analysis).[6] In addition, the project must also analyse similar projects and 'common practice' activities as a credibility check to complement the investment analysis or the barrier analysis.[7]

Although the quantitative approach of investment analyses is less subjective than barrier analyses, it still captures only one facet (i.e. economic/financial viability) of the many complex factors that prevent uptake and diffusion of new technologies/activities. While economic and

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financial barriers such as lack of appropriate return on investment (ROI), internal rate of return (IRR), or net present value (NPV) have received most of the attention, there are a number of other barriers – informational, technological, institutional, etc. – that may impede mitigation projects and activities. In fact, as Meyers (1999) points out, to a large extent it is the behaviour of actors that determines whether new projects are implemented or not. He suggests the notion of 'behaviour additionality' to capture the complex reasons underlying decisions taken by actors.

Extending Meyers' suggestion, we believe that mitigation projects are implemented (or not implemented) primarily based on the perception of 'project risk' by the developer. Investment uncertainty, technological uncertainty, policy and regulatory uncertainty, as well as barriers of the kind mentioned above, are all components of the risk viewed by the project developer. We believe that some project developers are greater risk-takers than others, and consequently will implement projects with a risk profile that most others are not willing to consider. Therefore, indicators such as economic internal rate of return (EIRR) or financial internal rate of return (FIRR) are not always a reliable guide to the additionality of investments by early adopters.

The actions of these risk-takers – innovators and early adopters – result in the implementation of 'early-bird' projects whose performance convinces other (more risk-averse) developers that these kinds of projects are acceptable investments. Unless such a transition to a more widespread acceptance of the investment viability of novel project activities occurs, we remain in a zone of uncertainty whereby further projects may not happen. Consequently, we believe that 'risk additionality' – i.e. the propensity of most project developers or implementers within firms to not take on these risks in the absence of CDM – is the key surrogate for emissions additionality in the CDM. Consequently, until a transition to more widespread adoption has occurred, projects in the early-adoption, high-risk phase need to be viewed as additional. The CER revenue reduces the overall project risk, and thus opens the door to the implementation of these projects by developers who are more risk-averse.[8]

3. CDM projects as diffusion of innovations

This notion of CDM relevance and risk additionality is best viewed within the framework of diffusion of innovations.[9] Placing such GHG mitigation efforts within the innovation-diffusion framework allows for a more integrative and synoptic perspective of mitigation activities rather than a focus on specific elements that might constitute barriers to deployment of new technologies or products. In addition, this also allows us to propose a simple analytical criterion for additionality that is based on the theory of adoption and diffusion of innovations, as will be seen later.

It is generally well accepted that the diffusion of innovations is characterized by an S-curve, as shown in Figure 1 (Mahajan and Peterson, 1985; Geroski, 2000; Rogers, 2003). The uptake of technology in the market is particularly slow during the initial phase and requires the presence of marketplace innovators who are willing to experiment with new ideas. As the diffusion proceeds, the rate of adoption increases, with a transition point corresponding to what is termed as 'take-off', as early adopters start building on the experiences of the innovators (Rogers, 2003). As the potential market for the innovation matures and a majority picks up the innovation, there is a slowdown in the rate of adoption and eventually the technology uptake becomes saturated.[10] The slope of the S-curve is different for different innovations and the curve may be asymmetric, depending on the characteristics of the innovation, the actors involved, and the policy, market, and social context of overall system (Geroski, 2000; Rogers, 2003). A range of mechanisms underlying the diffusion have been suggested for explaining the S-curve, including network creation, information dissemination, legitimation and competition, firm characteristics, technology

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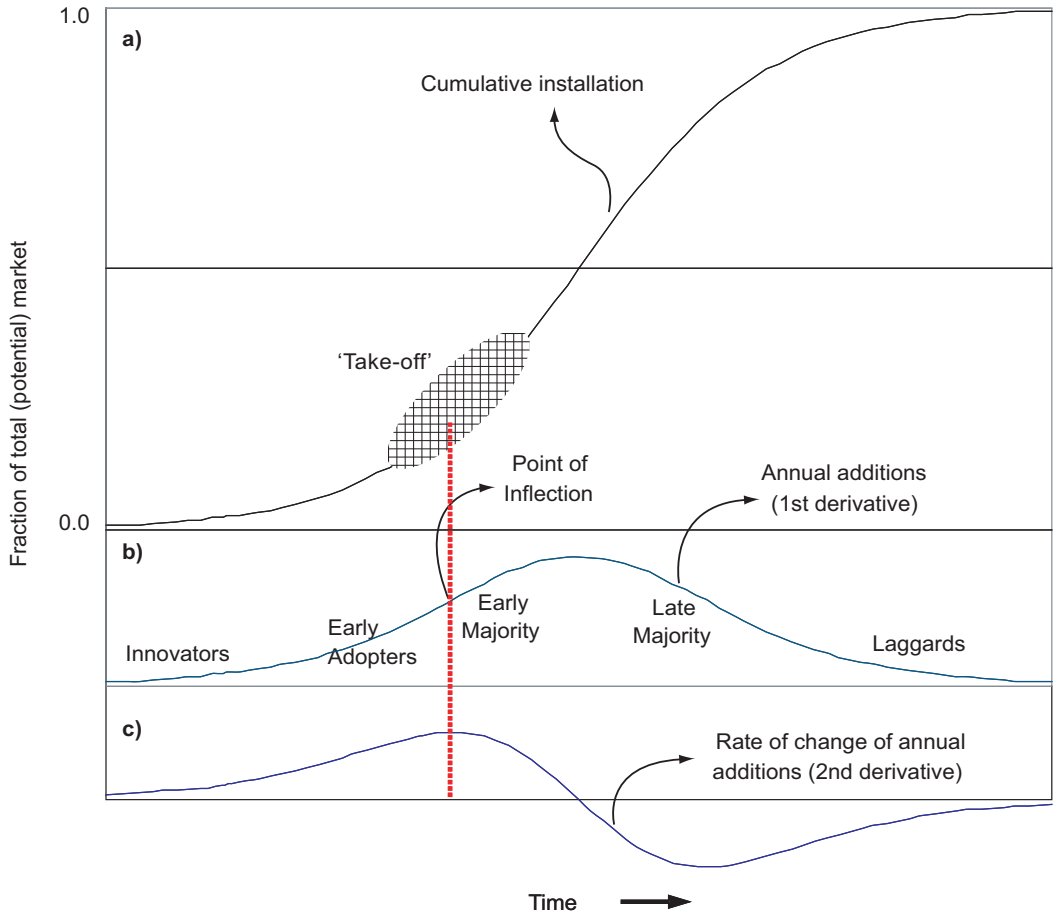

FIGURE 1. The cumulative S-curve and adopter categories. (a) The S-curve provides a general description of technology diffusion in the marketplace. The curve denotes the cumulative number of technology adoptions as a function of time. The 'take-off' occurs generally at about 10–20% of the total adoption (as indicated by the cross-hatched area). (b) The various adopter categories are shown on a normal distribution curve that indicates the annual technology additions. (c) The maximum in the first derivative of the annual installation curve (i.e. the second derivative of the cumulative installation curve) indicates the first point of inflection in the annual installation curve, which in turn corresponds to the take-off region. (Adapted from Rogers, 2003)

evolution, etc. (Mahajan and Peterson, 1985; Geroski, 2000; Rogers, 2003). Nakicenovic et al. (1993) specifically discuss the relevance of this innovation-diffusion framework to energy-technology transitions, and point out its salience to decarbonization.

Rather than dwell on the applicability of specific mechanisms that might underlie the diffusion of an innovation corresponding to a particular GHG mitigation project, we simply suggest that the early adoptions of such an innovation help overcome barriers to diffusion by creating a critical mass of users, improved communications, improving or legitimizing technology, developing supply chains, reducing price through 'learning-by-doing', etc. As these barriers are overcome and the risks relating to performance, cost, and reliability are lowered, the rate of diffusion increases

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to a take-off point, beyond which diffusion may become self-sustaining. But in the initial stages, before these barriers have been overcome to reach the take-off point, the diffusion of the innovation (i.e. the implementation of projects) is uncertain. Early adopters, therefore, represent a crucial link between the initial stage of the innovation diffusion and the take-off phase. In some cases, though, despite the presence of early adopters, many innovations may never reach the take-off stage or display the S-curve (Geroski, 2000; Rogers, 2003) – that is to say that in some cases, the diffusion of the innovation may not become self-sustaining even if the cumulative additions are beyond the take-off point. This may happen in cases where an innovation requires continued additional support (financial or otherwise) for it to be deployed, as in the case of technologies for many rural applications – this issue will be discussed further later. Just to re-emphasize, though, the key point to note here is that below the take-off point it is difficult, and often impossible, for the diffusion of an innovation to be self-sustaining.

We suggest that the take-off point, which can be estimated analytically on the basis of empirical data, be used to define the additionality criterion. Thus, a CDM project satisfies the additionality criteria if the diffusion of the relevant innovation is below the 'take-off' point in its S-curved diffusion process.

The take-off transition generally occurs at 10–20% of the total adoptions, depending on the exact shape of the S-curve (Rogers, 2003, pp. 12, 274; see also Figure 1a). This will be at or around the inflection point of the plot of annual installations/additions versus time, which is the point at which the rate of annual installation (i.e. the first derivative of the annual installation curve) is maximized (see Figure 1b,c). The position of the inflection point very much depends, as does the shape of the curve, on the particular characteristics of the innovation being adopted and its interactions with local conditions. Thus, innovations based on different technologies could have very different inflection points,[11] and similar innovations could show very different inflection points, as they are implemented across countries with different consumer, market, and policy characteristics. Therefore, rather than making assumptions about take-off threshold values, it is better to empirically determine the status of the innovation by examining its trajectory – in that sense, the past is the prologue.

By plotting the annual additions/installations over time to see whether an inflection point has been reached (or by taking the time-derivative of this data to see whether a maximum has been reached), one should be able to empirically assess whether a particular 'innovation' that forms the core of a proposed CDM project activity has reached take-off or not.

4. Defining the relevant 'adoption space'

The question that arises is how to define the 'adoption space' for a particular innovation for CDM purposes, i.e. how does one define an 'innovation' in order to put together the adoption curve discussed above? First of all, given that innovation diffusion is mostly determined by the existing policy and regulatory regimes and the socio-economic context in a country, it is important to consider only the cumulative additions of an innovation within a particular country, and not additions across countries for determining the innovation-adoption curve. As a corollary, innovations that are being tried out for the first time in a country, by definition should be considered additional in the CDM context.

But how to evaluate whether the implementation of a technology is an 'innovation', if this technology has already been used in some applications in the country (in some specific markets or firms)? We suggest that, for the purposes of the CDM, a GHG-mitigating 'innovation' should be thought of as a new implementation of a technology (or a product embodying a technology)

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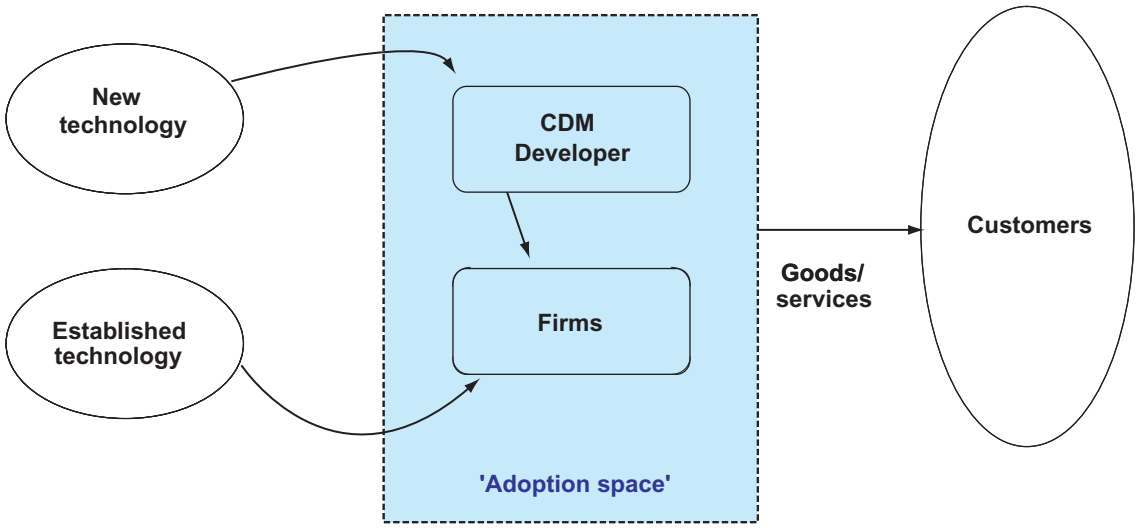

FIGURE 2. Illustration of 'adoption space' for evaluating a potential CDM project.

in a particular market segment. The market segment, in turn, is defined in terms of the competition space for the goods/services that are being provided by the implementing firm (since this is the space in which a firm views/experiences risk). Thus the market (or the relevant 'adoption space') includes all firms that provide these goods/services to their customers (see Figure 2). We illustrate this with two examples.

Example 1: If the project is a grid-connected wind farm, then the technology is a windmill and the corresponding market is the grid-power market (since the product of the wind farm, i.e. the generated power, competes with other sources of power in the grid). If the implementation of windmills for grid-power is new to the country, then the project should be considered as additional. On the other hand, if the project is a wind farm for providing power to remote rural areas, then the relevant market is stand-alone rural power (where it might compete, for example, with diesel gensets). If the implementation of wind farms for these markets is novel, then these projects should be considered for CDM credits, even if windmills are being widely used in the grid-power market.

Example 2: If the technology is a novel energy-saving control system for a steel mill, then the relevant market segment is the steel market. But if a project based on implementation of this technology in small firms is asking for a CDM status with the rationale that this technology has not been implemented in small firms, even though it is widespread among large steel manufacturers, we believe this project should not be considered CDM. These small firms compete with large firms in the steel market and therefore already make their business decisions with this competition in mind (and therefore would have to consider taking on the risk of implementing this energy-saving technology in any case to stay competitive).

Our approach is different than that proposed recently by Kartha et al. (2005), who suggest using market penetration rates for determining the additionality of technologies used in CDM projects. They suggest the use of market share and market saturation data to determine penetration rates.

Mathur.pmd 235 11/10/2007, 10:39 AM

However, they do not define the overall 'market' for particular technologies. Furthermore, assessing the size of the overall market is difficult, since it requires an understanding of all the potential implementers/consumers.[12] Therefore, our approach – based on the empirical examination of cumulative additions of a specific innovation to ascertain whether an inflection point has been reached – obviates the need for assessing the size of the overall market. It only requires the availability of information about total numbers of additions/implementations as a function of time. We recognize that even this may be an onerous burden, but public data collection efforts could help in this regard. Kartha et al. (2005) have listed a set of data collection approaches and their advantages and disadvantages for estimating the take-off point for a given innovation. We suggest that the national CDM coordination agency, along with project developers, determine the appropriate set of data needed for such estimations. In fact, the inclusion of such common practice analysis might encourage both the national CDM coordination agency (i.e. the Designated National Authority) and project developers to jointly set up relevant data collection systems in developing countries.

As mentioned earlier, this model does not directly consider economic or other barriers, or suggest criteria based on such specific barriers; rather it assesses additionality in terms of how potential adopters view risk at the early stages of diffusion of the innovation or technology (which, in turn, incorporates these other elements/barriers). Specifically it suggests that projects that are based on concepts or technologies that have not yet reached take-off stage for specific applications may not be widely deployed unless supported by extra incentives such as CDM. There is no shortage of ideas or innovations that have not taken off, but the assumption here is that it is worthwhile for the CDM to support innovations with positive climate externalities. In effect, developers who are proposing CDM projects based on innovations that have not yet reached take-off stage are pursuing risks in addition to those that they might otherwise bear. Of course, if the project is approved as a CDM project, the onus is on the developer to effectively address various barriers to make the project a success. In this sense, we believe that specific barrier analyses for projects are not necessary, and that having a definitive additionality test such as we have envisioned here would streamline the CDM process and enhance the uptake of advanced, emerging technologies (see also Kartha et al. 2005).[13] The notion of 'risk additionality' also adds emphasis to the role of innovators and early adopters in advancing CDM, and indeed, clean development in developing countries.

We also note that some kinds of projects, which have reached the take-off stage and could be considered common practice, might still need support from the CDM to be economically viable. This builds on our earlier point that for the deployment of some technologies, reaching the take-off point need not mean that the deployment becomes self-sustaining. For example, projects involving the capture of methane from municipal solid waste (MSW) are not financially viable without CDM support, since the generation of power from the methane does not by itself yield adequate revenues to make the project worthwhile. Therefore, such activities would need continuous support from the CDM even after they are widely deployed and may be beyond the take-off point.

In this context, a modified 'additionality tool' is proposed. This obviates the need to demonstrate financial non-viability without CDM revenues or non-implementation because of other barriers. Instead, the tool, shown in Figure 3, provides a simple analytical and empirical rule to the common practice criterion. Steps 0 and 1 of the modified tool are the same as the current formulation. Step 2 directly leads to a 'common practice analysis' wherein the project's key innovation is assessed against the empirical data for the deployment of similar technologies in the relevant adoption space. If the innovation is below the 'take-off' point, as discussed earlier, then the project is

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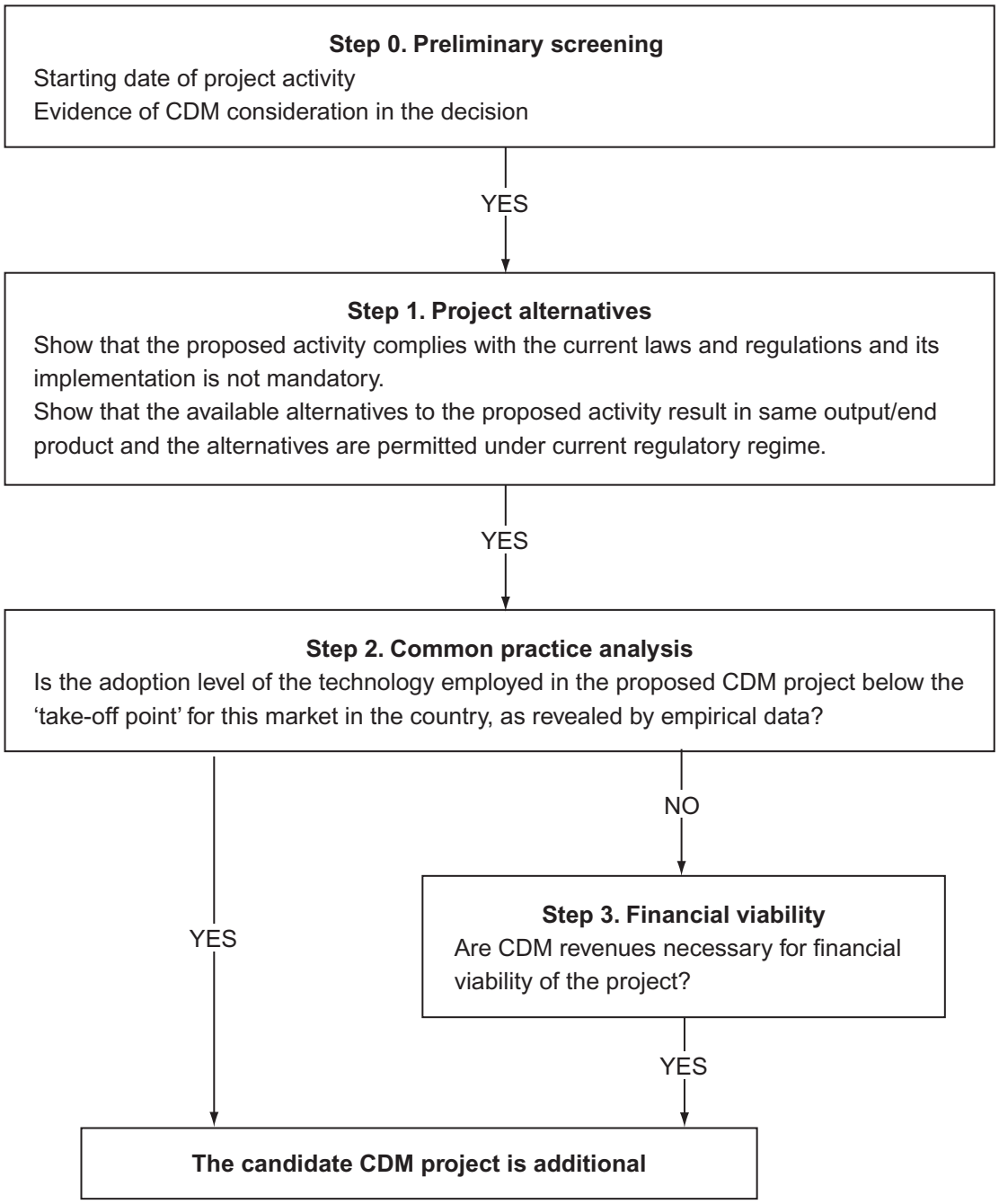

FIGURE 3. Modified tool for demonstration of additionality.

considered additional. If not, the project can still be considered additional if its financial viability is dependent on CDM revenue. In this sense, the financial viability analysis is needed only for an innovation that is already the 'common practice'.

Mathur.pmd 237 11/10/2007, 10:39 AM

One final point: given that the ultimate aim of the CDM is to assist in sustainable development in non-Annex I countries, we believe that special attention should be paid to projects that are part of larger corporate programmes or national policy initiatives that intend to build on the experience of a given (set of) project(s) and thus help scale-up the implementation of such project(s). This would help to ensure that the CDM project is not just a one-off intervention but one that helps transform the relevant component of the energy sector in such countries, and move them on to a cleaner sustainable energy trajectory. Such a policy of giving special attention to projects with greater potential for replication/scale-up will engender synergies between individual projects and corporate strategies/national policies, and ultimately make a bigger contribution to progress towards meeting the goals of the UNFCCC.

This last suggestion is at odds with the current perception that CDM projects should not be driven by national/corporate strategy, since that might violate the existing additionality criterion. However, we believe that the 'take-off criterion', based on risk additionality, addresses this concern. It would also allow corporate, national and international goals to be aligned so as to reach the take-off of GHG mitigation innovations as early as possible and therefore contribute towards faster implementation of 'clean development'. We believe that a concept of 'programme of activities', adopted by the CDM Executive Board, will help stimulate such transformations.

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Notes

1. Although some commentators have characterized CERs as a subsidy for technologies in developing countries (see, for example, Chomitz, 1998), we believe that CO_2 emission reductions (CERs) are now well-defined marketized commodities, since the Kyoto Protocol has created a market within which CER revenue is payment for a 'coproduct'.
2. See paragraph 43 of the draft MOP resolution appended to Decision 17/CP.7 of the Conference of the Parties to the UNFCCC.
3. See http://cdm.unfccc.int/methodologies/PAmethodologies/AdditionalityTools/Additionality_tool.pdf for the latest version of the tool.
4. The Executive Board does allow for the project developers to propose new methodologies including new definitions of additionality; although it is not clear whether radical alterations of existing definitions would be acceptable.
5. 'Step 0' of the additionality tool requires developers to 'provide evidence that the incentive from CDM was seriously considered in the decision to proceed with the project activity'.
6. See Step 2 and Step 3 of the additionality tool.
7. See Step 4 (common practice analysis) of the additionality tool.
8. See, for example, Mathur et al. (2006).
9. An innovation can be broadly defined as 'an idea, practice, or object that is perceived as new by individuals or by other units of adoption' (Rogers, 2003). In the context of GHG mitigation projects, the core idea, technology or product underlying a novel, actionable mitigation project can be considered as the innovation.

Mathur.pmd 238 11/10/2007, 10:39 AM

10. Technologies eventually begin to face competition from superior technologies and lose market share. In this article, we are mainly concerned with uptake of technologies, and hence do not consider the senescence of technologies.
11. For example, consumer technologies can take off at low levels of market penetration (Golder and Tellis, 1997), although this still implies large numbers of units deployed.
12. Defining the size of the total 'market' is difficult for many reasons – for example, in the case of wind power, it is not at all clear how to estimate the total market for off-grid or on-grid applications.
13. A partial crediting approach, similar to that proposed by Kartha et al. (2005), could be instituted near the take-off point to reduce the high sensitivity that arises from choosing a specific 'take-off' point.

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