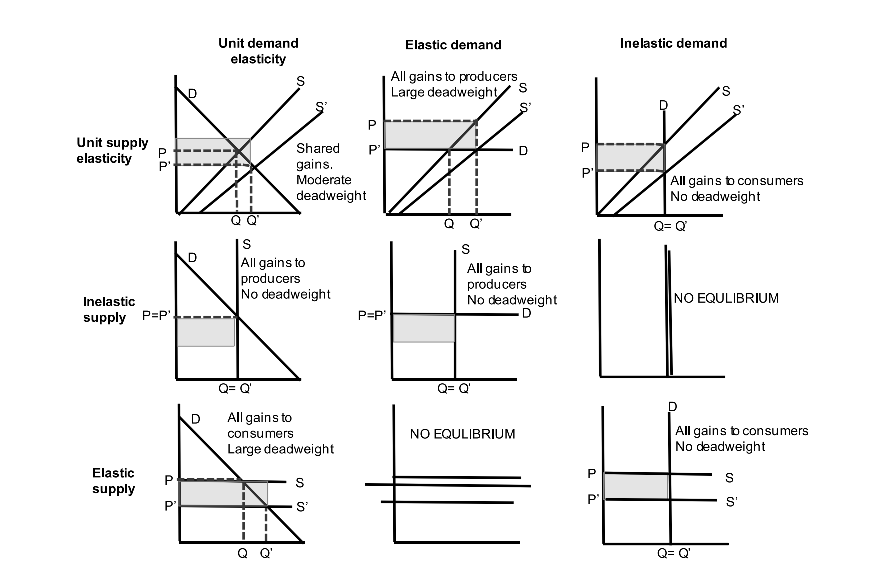
APPENDIX 1:

Effects of different output supply and demand elasticities on producer and consumer gains from input subsidies



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Integrating developing country agriculture into global climate change mitigation efforts

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Introduction

Becoming integrated with global efforts to reduce greenhouse gas (GHG) emissions represents a major challenge for the agricultural sector in developing countries. Current efforts revolve around carbon offset projects purchased under the Clean Development Mechanism (CDM) by parties to the Kyoto Protocol in lieu of abatement by developing countries. However, because of transactions costs related to implementation, monitoring and verification of emission reductions, agriculture has seen very limited use under the CDM. Up to July 2009, agricultural activities accounted for only 6 percent of all approved CDM projects and only 4 percent of the total emissions reduced.

Agriculture is not only a main contributor to GHG emissions, it also offers a considerable potential for GHG mitigation. Developing countries alone account for 74 percent of the technical mitigation potential of world agriculture (Smith et al. 2007). More importantly, GHG emissions from developing country agriculture increased 32 percent from 1990-2005 while emissions from developed country agriculture declined 12 percent (UNFCC 2008b). The potential role of the agricultural

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sector in climate change mitigation is one of the issues currently under discussion in the Copenhagen negotiation process[2].

Sources of agriculture's reduction opportunities include emission reductions (manure management, enteric fermentation and fertilizer practices); biological sequestration fluxes (tillage, crop rotations, cover crops and grazing practices); avoided fossil fuel emissions from substitution for fossil fuels (with liquid transportation biofuels, thermal biopower/bioheat or renewable electrical power); and from efficiency improvement. Because deforestation is the largest source of emissions (that occurs mostly in developing countries) and is primarily caused by land conversion to agriculture, activities in land use, land use change and forestry (LULUCF) are closely related to agriculture. Not only can GHGs be released through land use change, GHGs can be sequestered through avoided deforestation and land degradation (REDD), afforestation and reforestation (A/R), and forest management (FM).

An underlying theme of this paper is that most of the mitigation potential in developing country agriculture is not in directly reducing output and fossil fuel consumption but from emission abatement activities, namely, changes in production practices and technologies (e.g., REDD, soil carbon sequestration practices, midseason drying of irrigated rice, nutrient management to reduce nitrous oxide emissions and livestock management)[3]. The implication is that carbon offsets represent an appropriate mechanism to subsidize abatement activities in developing country agriculture, unlike a cap and trade regime or environmental taxes. Hence, we develop a model that distinguishes marginal abatement costs (central to developing country agriculture) from output reduction costs where reductions in fossil fuel consumption are the primary driver of emission reductions in the industrial sector (as in cap and trade economies). We show that carbon offsets benefit both the cap and trade economy and developing countries. Because offsets reduce the total costs of emission reduction for cap and trade economies, the latter now have an incentive to further increase their emission reduction targets. Therefore, a limit on carbon offsets (as is currently the case for the European Union and in proposed U.S. legislation) hurt cap and trade economies. Although developing countries would benefit from more offsets, the cost to them of limiting the number of offsets may be more than compensated for by the higher price received for offsets with the resulting higher permit prices in cap and trade economies.

[2] This provides a unique opportunity to combine low-cost mitigation and essential adaptation outcomes with food security, poverty reduction and sustainable development. The goal is to have agriculture fully integrated in the current system of GHG reduction mechanisms and relevant negotiation processes, thereby benefiting from the related financing facilities.

[3] Numerous studies have documented the many different ways the agro-forestry sector can mitigate GHGs (UNFCC 2008b; Smith et al. 2007; Nelson 2009; FAO 2009a,b, 2008).

The case for public subsidies for abatement activities is further strengthened by the resulting correction of multiple market failures, potentially generating significant co-benefits to agricultural producers and society at large. In addition to contributing to the public good of reduced GHG emissions, there are several "technical" externalities reflecting the multifunctional nature of agricultural production[4]. Multiple non-commodity outputs are produced (both positive and negative technical externalities) and the correction of these market failures provides an additional rationale for public subsidies of emission abatement activities. Furthermore, because of knowledge externalities in technological innovation and both learning-by-doing and learning-by-using externalities in the adoption of new technologies, there is an additional market failure in the innovation and diffusion of abatement technologies and production practices itself. This requires further public expenditures in R&D, extension services and technology transfer packages.

The paper also addresses the implications for global trade if not all countries are party to a global carbon trading system by analyzing "market" leakage (where emissions are shifted to another location or sector). Leakage is traditionally defined as the increase in emissions in other countries due to GHG emission mitigation policies (e.g., cap and trade or REDD). The emissions increase in unregulated economies because environmental policies generate changes in market prices, trade and location of production. Leakage has to be distinguished from "shuffling" (where neither the location nor costs of production change but the environmental policy is nevertheless ineffective) and from "technical" leakage (differences in emissions intensity between regulated and unregulated economies can magnify or dampen our definition of market leakage above).

Although the literature only recognizes the "international" component of leakage, we show that emission mitigation policies in the agro-forestry sectors may have "domestic" leakages as well. These domestic leakages in some cases can outweigh international leakage. This means carbon tariffs can be counterproductive and increase total leakage. Carbon tariffs should also be adjusted downwards because of both agricultural subsidies in OECD countries adopting cap and trade, and for the reduction in emissions in these countries due to increases in output in developing country agriculture with the correction of multiple market failures with an effective carbon offset program. Carbon tariffs can also cause international shuffling where products exported to cap and trade economies use low carbon inputs while other products not exported use high carbon inputs. Furthermore, we show that the interaction effects between supply-side leakages (due to cost increases) and demand-side leakages (due to reductions in fossil fuel prices) needs to be considered.

[4] For a more detailed description of the multifunctional characteristics of agricultural production, see OECD (2001) and FAO (2007).

Carbon offsets reduce emissions through the carrot of financial subsidies rather than the stick of emission limitations as with cap and trade. Targeted subsidies (e.g., subsidies for clean technologies) are less vulnerable to leakage and shuffling because they do not impose costs on firms (supply-side leakages) or changes in consumption prices (demand-side leakages), so firms (consumers) have no incentive to relocate production (consumption) or avoid costs, unlike with a tax on emissions like cap and trade. Carbon offsets provide such a mechanism for targeted subsidies.

Not only do public subsidies for abatement minimize leakages, they also complement the unique feature of developing country agriculture's mitigation potential being in altered production practices while overcoming the high transactions costs associated with implementing project-based carbon offsets. A tax or permit scheme will be too difficult to apply to emission reductions that result from the modification of production processes. The best method to deal with leakage therefore reinforces other rationales for targeted subsidies for abatement activities.

But because of low returns, high risk and high transaction costs to verify real, additional and permanent GHG remission reductions for developing country agriculture associated with project-based carbon offsets (as is currently under the CDM), different financing mechanisms must be found. Project-based CDMs may not allow for the breadth and scale of incentives required to generate widespread changes in agricultural production systems. There have been a number of proposals to scale up funding and delivery mechanisms including programmatic, sectoral and policy CDMs (FAO 2008; UNFCC 2008a). These new mechanisms would be more relevant for developing country agriculture while complementary public sector funding like a Climate Fund to finance critical changes in developing country policies and infrastructure deals will also be needed (Burniaux et al. 2009).

In terms of financial flows to developing country agricultural sector, the efficiency of emission reductions and agricultural growth strategies, we conclude that abatement subsidy programs can be a win-win-win situation. But it also represents an opportunity to reconfigure domestic agricultural policy in developing countries. For example, subsidies for input use should be transformed into subsidies for the way in which production occurs like land management techniques to reduce emissions while at the same time enhancing productivity and rural incomes. Because of the large investment required to finance R&D and new institutions to deliver the altered production practices, it will also require more financial aid to developing countries upfront and to integrate the efforts to adapt to climate change with GHG emission mitigation efforts, along with long standing international aid and financing mechanisms.

Abatement subsidies should not run afoul of WTO law regarding subsidies, just as carbon offsets currently do not. In many cases, agricultural output will increase, reducing international prices and developed country agricultural output, generating positive international leakage as production is more energy intensive and mitigation potential much lower than in developing countries[5]. Furthermore, reductions in developed country agricultural subsidies will also aid in the efficacy of GHG mitigation efforts in developing countries.

The focus of the paper is to develop a conceptual framework on the basic economics of carbon offsets and assess issues like leakage. This is to provide basic principles and general guidelines for policymakers as to what an ideal policy would look like. The paper is organized as follows. The next section summarizes agriculture's role in the CDM while Section 3 develops a general economic model of carbon offsets and cap and trade. Section 4 develops a general model of leakages while Section 5 explains how targeted subsidies are a very appropriate policy response to global climate change in developing country agriculture. The final section provides some concluding remarks.

10.1 Current status of agriculture and CDM projects

Despite its large mitigation potential, agriculture is nevertheless not fully integrated in the current system of GHG reduction mechanisms and relevant negotiation processes. For instance, until very recently, agriculture was not included in the Copenhagen negotiation process nor has it benefited greatly from the existing financial mechanism created under the Kyoto Protocol. Hence, agriculture does not fully participate in and benefit from the related financing facilities. This section shows how little agriculture has benefited.

CDM agricultural projects are considered small-scale projects which have simplified procedures aimed to reduce the cost of applying for CDM approval. Several experts have concluded that many small-scale activities cannot be implemented cost-effectively, because the transaction costs related to project design, validation and verification are too high to be compensated by the project revenues. Nevertheless, small-scale projects have only had a slightly lower success rate than the overall average (86.3 versus 95.5 percent). Simplified accounting procedures can be used for small-scale projects, thereby contributing to reduced transaction costs during the project (preparation, monitoring, validation and certification). As of February 2009, 46 percent of all the CDM projects in the pipeline (2,049 out of 4,474) were small-scale. These are expected to generate around 10 percent of the CERs (certified emission reduction units) through 2012 (UNCTAD 2009a).

[5] This may not be the case for livestock production where emissions per unit of output are much higher in developing countries. Abatement subsidies are meant to reduce emission intensity by increasing productivity but it is still possible that that total world emissions increase.

Experience shows that some CDM projects perform worse than expected, while some have outperformed expectations. In early 2009, the overall CER issuance success rate has been approximately 98 percent, but there are large differences between categories. HFC (hydrofluorocarbon) and N2O (nitrous oxide) emissions reduction projects have performed better than expected, while projects for agriculture, geothermal energy, landfill gas recovery, methane capture and the transport sector have had a success rate less than 50 percent of initially expected CERs.

China dominates the number of CERs issued as of February 2009 with 42.3 percent of the total. In China, 90 percent of the issued projects are industrial HFC projects, but the situation is changing. India is the second largest supplier of CERs with 22.8 percent of market share, followed by Korea with 14.5 percent, Brazil with 11.4 percent, Mexico with 1.8 percent, Viet Nam with 1.2 percent, Chile with 1.2 percent and Egypt with 0.9 percent.

The CDM has successfully created a dynamic carbon market. By April 2009 it had issued 277 million tons of CO2e[6], generating 2.7 billion Euros in CDM investment at 10 Euros per tonne/ CO2e. As of 1 September 2009, there are 4,631 projects in the CDM pipeline and only 10 host countries accounted for 87 percent of all CDM projects. Projects were mostly under the renewable energy category and were concentrated in the Asia- Pacific and Latin America regions. Falling oil prices and signs of worldwide recession have caused a general decline in carbon market prices. European Union carbon prices for EUAs (European Union Allowances) fell from 28 Euros in June 2008 to 14 Euros in early December 2008, but then recovered towards the end of December 2008 to around 20 Euros, and then fell again in early 2009, temporarily touching the 10 Euro level[7].

Until early 2009, afforestation and reforestation (A/R) activities, although eligible under the Kyoto Protocol (unlike avoided deforestation and land degradation (REDD) and forest management (FM), hardly participated in the carbon market. The principal reasons are that they are not accepted in the EU ETS (emitting trade scheme), the primary market demander of CERs, and that they generate only temporary credits. The challenge remains as to how to preserve the environmental integrity and economic soundness of CDMs, while speeding up and streamlining

[6] The greenhouse gases at issue are mainly CO2, nitrous oxides and methane, expressed in CO2 equivalent units and referred to as CO2e. In this paper, we refer to CO2e as "greenhouse gases."

[7] CER prices for December 2009 were being traded at 14 Euros. In India, CERs arising out of the CDM have been sold for much less - only 5-10 Euros. It is not clear why this price difference exists. Ishani Chattopadhyay, Director of Ecosecurities, India, a carbon credit trader that buys CERs from India for sale in Annex I countries indicates there are risks for operating in developing countries and dealing with small companies, while there is no "stock exchange" for CERs yet, since the first CERs have only just been issued for sale on October 20 2005. CER's are bought and sold in private deals where prices are not revealed, so a fair price is difficult to arrive at. Mukul Sanwal of the UNFCCC agrees that greater transparency would result in higher prices.

the CDM project cycle (financial support for project developers, technology transfer and capacity-building needs).

In 2008, the EU ETS continued to dominate the carbon markets, accounting for two-thirds of the total carbon market volume and three-quarters of its value. Around 3.1 billion CO2e allowances were bought and sold in the ETS during 2008, with total value of 67 billion Euros. With regard to United Nations-backed carbon credits generated from the Kyoto Protocol's CDM, some 1.6 billion changed hands in 2008, with a value of 24 billion Euros. The secondary market for CDM credits (known officially as certified emissions reductions (CERs)), totalled 1 billion tonnes in 2008, corresponding to two thirds of the total CER market volume. Overall, the value of the CER market in 2008 increased by 70 percent, compared to 2007.

So far, the CDM projects are primarily renewable energy projects, from hydroelectric and wind to solar and geothermal. In terms of projects types, by the end of 2008, renewable energy technologies had a leading share of the pipeline with 63 percent, methane emission reduction projects accounted for 16 percent, and supply-side energy efficiency accounted for 10 percent. Afforestation and reforestation accounted for 0.8 percent.

Hydropower was the dominant CDM project technology, accounting for over 25 percent of the projects (i.e. 1,174 projects). Two thirds of those projects were located in China. India hosted over 110 hydropower projects, and Brazil hosted 70 hydropower projects. Biomass-based energy projects had a 15 percent share and wind energy projects had a 14 percent share in the pipeline.

Table 10.1 shows the number of total CDM projects up to July 2009. According to the UNFCCC (United Nations Framework Convention on Climate Change), the total number of projects is 4,280 (after subtracting the 533 CDM projects rejected) and the number of projects registered is 1,760 while a further 234 are in the registration process. UNEP Riso[8] shows that most of the rejected projects are by the DOE (designated operational entities). DOE first checks the validation requirement and then finalizes the validation process after the CDM methodology is approved by the CDM's Executive Board.

Table 10.2 shows the agriculture projects according to the UNFCC. There were a total of 127 agricultural projects up to July 2009, or 5.8 percent of all projects at validation. We have 13 CDM sectors other than agriculture which include energy (industry, distribution and demand), manufacturing industries, chemical industries, construction, transport (metro system), mineral production, metal production, solvent use, waste handling and disposal and afforestation/reforestation.

[8] The CDM/JI Pipeline Analysis and Database contains all CDM/JI projects that have been sent for validation/determination. It also contains the baseline and monitoring methodologies, a list of DOEs and several analyses. Almost all information is from cdm.unfccc.int and ji.unfccc.int.

Table 10.1
Status of CDM projects July 2009 (UNFCCC versus UNEP Riso Data)

	UNFCCC	UNEP RISO
Number of CDM projects		
At validation*	2,124	2,633
Request for registration	115	81
Request for review	29	20
Correction requested	70	69
Under review	35	35
Total in process of registration	249	205
Withdrawn	31	31
Rejected by executive board	116	116
Rejected by DOE	na	480
Total rejected	147	1,750
Total number of projects	**4,280**	**5,215**

* Validation process is the submission of the design project to DOE

In Table 10.2, we classify agricultural projects into three categories: emissions reductions, biological sequestration fluxes and avoided fossil fuel emissions. The emissions reduction projects have mostly been associated with animal waste management and controlled combustion. No projects have been allocated to biological sequestration. The avoided fossil fuel emissions category refers to biomass fuel. Note that most projects are on emission reductions and more than 50 percent of agriculture projects are small scale activities. The total agricultural projects generated 8,389,299 tonnes of CO2e reductions per annum.

Some projects classified outside of the agriculture sector by UNFCC are common to agriculture with products such as bagasse and biomass residues (bagasse, corn, cotton and wheat straw, rice, maize stalks, etc.). We include these projects in the total number of agriculture projects in Table 10.3. As a result, there are 56 "agriculture" and 4 "forestry" projects, and a total of 813 energy industry registered projects. When the number of agriculture projects in Table 10.2 is added to the number of "agriculture" products in Table 10.3, there are 178 registered agricultural projects and 10 total forestry projects. Therefore, the total amount of agriculture CO2e reductions is approximately 11,910,915 tonnes per annum under our revised definition of agriculture, not 8,389,299 tonnes as described above. At current carbon prices of about 14 Euros per tonne, and given that the price of offsets are discounted due to various risks and transactions costs by approximately 20 percent, the total value of carbon offsets for agriculture at today's prices amounts to an approximately 133 million Euros, a paltry sum in the scheme of things.

The total amount of forestry CO2e reductions is approximately 696,612 tonnes per annum, not 281,431 for 6 projects as shown in Table 10.4. China hosts 59 percent of the CERs. China hosts 20 percent of CO2e reductions in agriculture compared to 31 percent for Brazil.

TABLE 10.2

Total CO2e reductions and the total number of agricultural CDM projects from 2005 to June 2009

Sources of Greehouse Gas Reductions	CO2e reductions (tonnes per annum)	Number of Projects	
		Total*	Rejected
Small Scale			
Emissions Reductions** 3	,525,637	67	1
Biological Sequestration Fluxes	-	-	-
Avoided Fosssil Fuel Emissions***	811,683	5	-
Large Scale			
Emissions Reductions	4,051,979	55	1
Biological Sequestration Fluxes	-	0	-
Avoided Fosssil Fuel Emissions	-	0	-
Total			
Emissions Reductions	7,577,616	122	2
Biological Sequestration Fluxes	-	-	-
Avoided Fosssil Fuel Emissions	811,683	5	-
Total	8,389,299	127	2
All other projects (excluding agriculture)			
Small Scale	23,678,127	872	50
Large Scale	328,756,677	16,207	6
Total	352,434,804	21,079	16

* Includes projects rejected and withdrawn.
** Emissions Reductions refer to animal waste management, avoidance of methane production from biomass decay through controlled combustion and methane recovery.
*** Avoided Fossil Fuel Emissions refer to biomass fuel for power generation such as wood residues, rice rusks and others (not bagasse).
122 agricultural projects registered with 8,279,205 tonnes of CO2e reductions per annum
Source: calculated

Table 10.3

Energy Industry CDM Projects from June 2005 to July 2009

	Reductions CO_2e per annum	Number of projects	
		Registered	Rejected
Registered and requesting registrations			
Large and small scale **			
Agriculture (bagasse and biomass)	3,521,616	56	7
Forestry (biomass)	415,181	4	2
Total all other projects from energy*	139,019,275	813	52

* Excludes 52 rejected and 11 withdrawn
** Five small scale projects (one agriculture)
Source: calculated

Table 10.4

Registered forestry CDM projects from November 2006 to June 2009

	Reductions of CO_2e per annum (tonnes)	Number of projects
Afforestation and reforestation		
Small scale	18,602	3
Large scale	262,829	3
Total	281,431	6

Source: calculated

There are many reasons given for why the CDM may not have successfully worked in agriculture[9]. Most of the reasons centre on the transactions costs of implementation including the ability to measure, control and monitor GHG emission reductions. The complexity of developing baselines and the concerns of being able to monitor in order to ensure additionality and permanence have plagued agriculture. Many papers have addressed this issue (Schneider 2007; UNCTAD 2009a,b; Muller 2009; Figueres 2009). Clearly, the project-based offsets approach under the CDM needs to be reformed in order to capture the full potential of agricultural mitigation. We delay our discussion of policy options being discussed in the literature.

[9] The CDM is one of three Kyoto protocol flexibility mechanisms, the others being the Joint Implementation and the International Emissions Trading mechanism. Joint Implementation is like the CDM but with projects in other Annex I countries instead of developing countries. These projects are expected to give CDM projects in developing countries serious competition. International Emissions trading provides each Annex I country with a certain number of emission allowances in line with its Kyoto reduction targets. If a country's GHG emissions are below their emission allowances (i.e., meeting Kyoto targets), they can sell these allowances to other Annex I countries that are emitting above the allowance (i.e., not meeting their Kyoto targets).

The next section first explains the economics of carbon offsets associated with a cap and trade regime.

10.2 The economics of carbon offsets with cap and trade

GHG emissions can be dealt with by either reducing fossil fuel use, thereby directly reducing output, or by investing in abatement activities that directly reduce emissions per unit output, or a combination thereof. Although society benefits from the reduced GHG emissions, society incurs curtailment costs in terms of a loss in social surplus due to output reduction, and direct resource costs associated with abatement activities. Abatement is defined here as changes in production practices (like using different technologies or ways in which inputs are used) with only indirect effects on output and fossil fuel consumption. For agricultural production, especially in developing countries, output could actually increase as a result of abatement activities. This is because agricultural commodities are jointly produced with technical externalities, be they positive or negative. Once these negative externalities are reduced or positive externalities realized, subsidies for abatement (e.g., through carbon offsets) can generate co-benefits that could increase output and improve rural incomes. However, it is not always the case that payments for environmental services increase agricultural output and rural incomes in developing countries (FAO 2007).

Co-benefits from abatement subsidies can also occur because of the public good nature of abatement activities itself: there are market failures with the innovation and diffusion of abatement activities (e.g., new technologies). Market failures associated with the sub-optimal provision of abatement activities interact with the market failures associated with not pricing public goods (or "bads" as in the case of GHG emissions) and technical externalities (either positive or negative like local water pollution from agricultural production)[10].

The realization that the process of abatement activities is itself characterized by market failures seemingly complicates the analysis but in the case of GHG emissions and developing country agriculture, it reinforces the efficacy of using abatement subsidies. Two mutually reinforcing sets of market failures are at work, both of which reduce the social optimal level of (1) abatement activities in developing country agricultural production; and (2) investment in the development and diffusion of new technology. There are therefore two sets of optimal policies: one to develop environmental policies that internalize both the negative and positive

[10]Because of non-excludability and non-rivalry, governments supply the public goods while negative (positive) technical externalities are dealt by taxes (subsidies). Because of transactions costs, taxes and subsidies for externalities are difficult to implement so subsidies for abatement activities are proposed here as an alternative.

externalities from agricultural production (e.g., emissions tax and amenity subsidy, or in the case for developing country agriculture we are proposing here, subsidies for abatement activities) that allow the private sector to choose the optimal mix of abatement activities and output reduction. The other is to implement policies that directly encourage the development and adoption of environmentally friendly production practices.

But because of the unique situation developing country agriculture faces, it is not always politically or administratively feasible to enact emissions taxes or a cap and trade regime. The transactions cost of implementing emissions taxes are too high (like often is the case for project based carbon offsets) while low rural incomes precludes the political feasibility of environmental fees. Meanwhile, emission taxes like a cap and trade regime are more relevant in situations where the biggest benefits in emission reductions is in reducing fossil fuel consumption directly. But most of the potential for mitigating emissions in developing country agriculture is not in the form of reducing fossil fuel use (e.g., reducing output) but by changing production practices (e.g., change in soil and crop management technologies and practices to increase soil carbon sequestration). Therefore, it is better to have subsidies for abatement activities that can directly correct both categories of market failures identified above simultaneously[11]. Hence, the optimal policy to correct the externality reinforces the correction of the second market failure of under-provision of innovation and diffusion for new production practices. Meanwhile, these abatement subsidies will increase agricultural productivity and production, generating pecuniary externalities through contributions to the economic and social viability of rural areas by underpinning food security, poverty reduction and economic development.

The discussion now turns to the sources of these two categories of market failures that result in the centrality of abatement activities as a correction mechanism. Then, the implications for carbon offsets are derived; namely, carbon offsets provide a means to subsidize abatement activities.

Market failures associated with jointness in commodity production

The overriding feature of agricultural production is its "multifunctional" character. Agriculture produces not only the private good (the food, fiber and materials that are the commodity outputs of agriculture) but also non-commodity outputs (OECD 2001). Non-commodity outputs of agriculture that are jointly produced with the commodity provide social values (or impose social costs) that are not reflected in the

[11]Because of transactions costs with the implementation of project-based carbon offsets, other approaches to transfer revenues for emission mitigation in developing country agriculture are recommended like a sectoral approach or a program based approach that induces farmers to employ different production practices (Burniaux et al. 2009; UNFCC 2008b).

market. Jointness in production can arise when non-allocable inputs are used in the production of multiple outputs (e.g., outputs are obtained from one and the same input). For example, the joint production of a commodity, landscape amenities and water pollution represents multifunctionality.

Rice production is one example where important multifunctional attributes result from non-allocable inputs used in the production of multiple outputs (Boisvert and Chang 2006). Several non-commodity outputs are jointly produced with rice, with some of them exhibiting characteristics of externalities or public goods. For example, the recharge of underground aquifers is an important multifunctional attribute of paddy rice production as well as the amelioration of land subsidence (the lowering of land-surface elevation from changes that take place underground). Furthermore, paddy rice production reduces flooding and soil erosion, changes the quality of the water and air, and provides landscape amenities. There are both positive multifunctional outputs (e.g., groundwater recharge) and negative multifunctional outputs (e.g., GHG emissions associated with the release of methane gas).

These non-commodity outputs are jointly produced with rice since groundwater recharge is directly related to total land planted to paddy rice and the intensity of the application of irrigation water. It is therefore impossible to disentangle the contribution of these two inputs to the production of rice from their contribution to groundwater recharge. Similarly, the contributions of land, water and fertilizer to rice production cannot be separated from their effects on the release of methane. For example, methane released during rice production depends on the water regime (e.g., deepwater rice fields generate significant amounts of methane). Methane emissions from rice fields also depend on several other factors like soil type, tillage management, residues, fertilizer practices and rice cultivar (Wassmann, Hosen and Sumflueth 2009; Boisvert and Chang 2006).

Because we cannot separate the contributions of the commodity, negative externalities and positive amenities, production is joint. But even with the joint, multifunctional production of commodity and non-commodity outputs like amenities and pollution, they are unlikely to be produced in fixed proportions with the agricultural commodity. This means policies should be directed to each externality directly. But it is difficult to observe and monitor the supply of environmental attribute associated with agricultural production. One cannot disentangle or separate out contribution of each input of each product. So subsidizing abatement activities through changes in production processes and input mix gets at the problem indirectly but in a more efficient manner. Furthermore, when there are positive and negative externalities simultaneously, one needs to subsidize the positive externality and tax the polluting input separately. One cannot calculate the net benefit and have a net tax (either negative or positive) – see Peterson, Boisvert and de Gorter (2002).

Production relationships underlying the multiple outputs of agriculture and their externality and public good effects can be released from this jointness (changes in farming technologies and practices can reduce the link between environmental outputs and commodity production). Technology widens the possibility of technical substitution between inputs. With changes in farming practices (e.g., from intensive to extensive) and optimization of non-commodity, productivity along with output is expected to increase. Subsidies for abatement technologies (e.g., technological change) and changes in agricultural production practices will be more efficient policies (not simply taxing or subsidizing the production of the commodity). Returning to our example of rice production, methane emissions can be reduced substantially by changing organic inputs and water management, the latter with midseason drainage and intermittent irrigation (Wassmann, Hosen and Sumfleth 2009; Nelson et al. 2009).

Market failures associated with the provision of abatement activities

Abatement activities improve social welfare because it reduces the cost of reducing GHG emissions while simultaneously providing co-benefits in the form of reduced negative externalities and increased positive externalities. But this assumes the optimal level of abatement technology exists. However, the social benefits from abatement activities can be greatly enhanced with public investment that generates new technologies and production practices (innovation through research) and the process by which new technologies are adopted (farmers have to learn about how to use them so, for example, extension activities must be a complementary policy). Independent of externalities from agricultural production, innovation and diffusion are both characterized by externalities as well as other market failures.

Innovation creates positive externalities in the form of new knowledge, which creates knowledge spillovers and so the market will not invest in the optimal level of innovation. There are also externalities in the adoption and diffusion of new technology. There is a benefit with the overall scale of technology adoption called "dynamic increasing returns" (Jaffe, Newell and Stavins 2005). Dynamic increasing returns can be generated by the user of new technology called learning-by-using (one user generates a positive externality to another user), or by the producer of the new technology through learning-by-doing (costs of production fall with experience). Network externalities can also exist where the benefits of a technology to an individual increases as other users adopt a compatible product (e.g., synergies in fertilizer application procedures with other land use practices that reduce emissions).

Both innovation and diffusion are characterized by additional market failures like incomplete information, and uncertainty (e.g., the uncertainty of the impacts of global warming on agriculture and the need for adaptation and the interaction effects with mitigation activities). New production practices are important for GHG emissions mitigation because with joint production, GHG emissions are generated at the same time as other negative and positive technical externalities, while abatement activities are underprovided. The subsidization of abatement activities is justified at the nexus of two distinct market failures; otherwise, abatement activities are doubly underprovided.

In many cases, and especially for developing country agriculture, abatement activities will only occur with public sector involvement through public good investments that change the technology (e.g., R&D expenditures) and public subsidies for programs that change production practices (e.g., expenditures for extension programs). Soil sequestration practices would be an example of abatement although indirect effects on output are inevitable. In some cases, especially for REDD activities and biofuel production, the market is directly affected: reducing the supplies of wood and shifting land into biofuels will have direct impacts on the market for wood products and land uses for agricultural products, respectively. There exists alternative abatement activities that reduce GHG emissions but also provide ancillary benefits in the form of improved productivity, lower cost (e.g., less water usage) and reduced pollution from agricultural production (e.g., pest control measures), thereby reducing social and environmental costs.

The central role of carbon offsets and abatement activities

Carbon offsets represents one mechanism to finance abatement activities. However, carbon offsets are designed to be implemented on a project basis. This means transactions cost in monitoring, reporting and verification of emission reductions. Additional complementary policies that finance abatement activities are required. In addition to the political and administrative difficulties of introducing carbon taxes in developing country agriculture, it is also more practical to subsidize abatement activities because the majority of GHG emissions mitigation is in the form of *changes in production practices* where most of the carbon emission mitigation potential exists in agriculture (not in reducing fossil fuel consumption). For example, most emissions from livestock is from enteric fermentation and manure, indirect emissions from manure storage, application and deposition, land use conversion for livestock grazing, and emissions related to pasture (94 percent of emissions are from production practices[12] while the remaining 6 percent of emissions are due to fossil fuel consumption in the life-cycle of livestock production – see Gerber and Steinfeld 2009). Abatement can be viewed as the biophysical outcomes generated by changes in the management of natural resources and the environment through

[12]This includes, however, "on-farm fossil fuel use" which we were unable to separate out and put in the category of fossil fuel consumption.

changes in agricultural production practices (the way in which you produce) and input mix (the type of inputs used)[13].

The technical potential for mitigating GHG emissions from livestock production varies among systems but subsidies to change production practices such as the capturing and burning of methane from manure management systems, and improving manure application techniques, fertilizer efficiency, rumen fermentation efficiency, feeding practices, livestock genetics, herd health and fertility, and land-use efficiency of livestock production (FAO 2009b).

As shown in the next section of this paper, carbon offsets also involve less leakage and shuffling because a carbon offset reduces emissions through altered production practices due to targeted subsidies, rather than reducing fossil fuel consumption directly. Abatement subsidies are therefore important for at least three reasons. First, the potential for GHG mitigation in developing country agriculture is mostly in terms of changing production practices; not reducing fossil fuel use although fossil fuel use per unit output will be reduced with enhanced productivity even though total output may increase. Second, there exists multiple co-benefits by altering production practices and so abatement subsidies, in addition to correcting for two key sources of market failures, also provide pecuniary externalities by being a key component for productivity improvement, poverty reduction and sustainable development. Third, a tax or permit scheme will be difficult to apply to emissions reductions that result from modification of production practices, especially for smallholder agriculture (like project-based CDMs).

In lieu of abatement (verifiable GHG emission reductions) by the unregulated sectors (e.g., developing country agriculture), parties to the Kyoto Protocol can purchase carbon offsets and therefore have unused allowances (or permits). Offsets are therefore subsidies to reduce pollution (unlike allowances in regulated economies that are a maximum on GHG emissions allowed and hence act as a tax on emissions). Offsets are therefore subsidies financed by either the public sector in regulated economies (if allowances are handed out to companies) or the regulated firms (if allowances are auctioned) through the international marketplace. Instead of having production limited by allowances, developing countries can mitigate GHG emissions through abatement activities. We now turn to the economics of carbon offsets with a cap and trade regime.

Economics of output reduction versus abatement

The objective here is to develop a framework that clearly distinguishes between abatement (e.g., generated by carbon offset revenues) and output reduction

[13]For an excellent summary of the agricultural science and technology needs for climate change mitigation and adaptation in developing country agriculture, see Nelson (2009).

(e.g., firms will reduce fossil fuel consumption directly when subject to an upper bound on emissions through the issuance of emission allowances or permits). We operationalize the methodology for analyzing carbon offsets for developing country agriculture[14]. The literature typically does not make a distinction between abatement and output reduction (Parry 2003; Bovenburg and Goulder 2002)[15]. But under our assumptions here, an emissions tax has the same effect as an output tax on efficiency. We will explain the implications of relaxing these assumptions later.

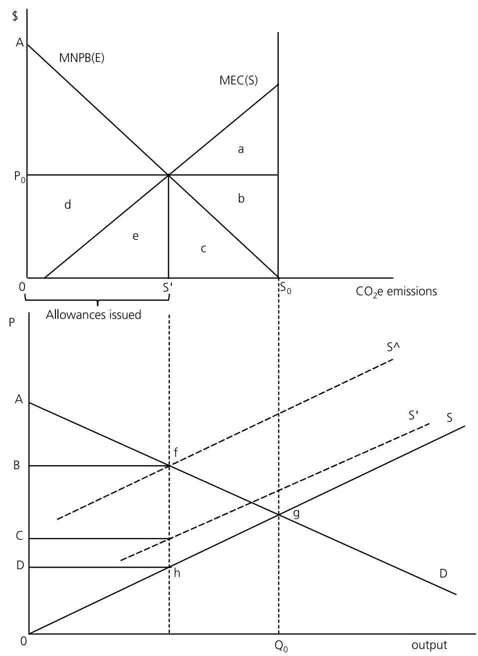
Consider the production of good Q which generates an externality (i.e., GHG emissions). Abatement activities A can reduce emissions without affecting the production of good Q (e.g., methane capture from a manure facility does not necessarily affect the level and mix of other inputs used in the production of that commodity). The production of the good generates *gross* GHG emissions E(Q). *Net* GHGs emitted (S) is defined as gross emissions minus abatement: S = E(Q) - A. Thus, emissions generated (referred to as gross emissions) is the sum of emissions released (referred to as net emissions) and emissions abated, all measured in identical units (Schamel and de Gorter 1996). Note that gross emissions may either be released in the environment inducing emissions damages or abated entailing abatement costs. Monetary external costs (damages) due to net emissions EC(S) = EC[E(Q) - A] are convex in S and marginal external costs are given by MEC(S).

Figure 10.1 shows the traditional model of optimal GHG emissions for the regulated economies subject to cap and trade. The *vertical* difference in supply and demand for the commodity in the bottom panel defines the marginal net private benefits curve (MNPB) in the top panel (distance 0A are equal in each panel). The intersection of the MNPB and MEC curves gives the social optimum level of emissions S′. Introducing a cap and trade scheme that limits emissions to the quantity S′ generates a price for the allowances of P_0 in the top panel of Figure 10.1 (equal to the distance BD per unit output in the bottom panel). This price of emissions represents an opportunity cost to firms of an additional unit of emissions in terms of having to purchase it or of otherwise not selling it. One can think of this emissions tax as an output tax that shifts the supply curve up to S^ in the 2^{nd} panel of Figure 10.1, moving along the MNPB curve to point S′. Emission reductions result in an increase in social welfare of areas *a* + *b* + *c*. The social costs of output reduction is given by area *c* (equal to area *fgh* in the bottom panel), for a net gain of areas *a* + *b*. The value of allowances is area *d* + *e* (these can be auctioned in which

[14]By distinguishing CO2e emissions reduction via output reduction and pollution abatement, the benefits and costs of abatement are integrated into conventional partial-equilibrium welfare analysis. This allows for a clear assessment of the social welfare implications of cap and trade with carbon offsets. In reality, some abatement will also occur with output reduction in a cap and trade regime, the implications of which are dicussed later.

[15]Schamel and de Gorter (1996) review the earlier literature that evaluates either abatement or output reduction, or excludes abatement by assuming the marginal costs of abatement exceeds the marginal social cost of reducing output over the relevant range of pollution reduction, or defines pollution as a function of pollution increasing and pollution decreasing inputs only.

FIGURE 10.1
Optimal emissions with output reduction only in regulated sector subject to Cap and trade



case becomes part of government taxpayer revenues or allowances can be handed out to firms; the market outcome is the same).

In developing countries, there is no incentive for the firm to invest in abatement technologies (e.g., methane capture), even though it may be the least cost way of reducing emissions, because of the public good nature of GHG emissions. Introducing the Clean Development Mechanism (CDM) allows regulated firms to purchase carbon offsets from developing countries in place of purchasing or using emission permits. Abatement activities A in developing country agriculture can reduce pollution levels *without* affecting production of good Q. For example, capturing methane from manure facilities is a situation where a farm would otherwise not reduce GHG emissions but a subsidy will induce it to. Installing methane capture facilities will therefore not directly affect agricultural output. Hence, GHG emissions are reduced through abatement only. Revenues from a carbon offset project that captures methane does not necessarily affect the level and mix of other inputs used in the production of that commodity[16]. This assumption is less realistic for carbon offsets designed specifically for REDD or biofuels where there is an impact on production and the market – the discussion of leakage is delayed until the next section of the paper.

The distinction between abatement and output reduction (and the interaction between the two) allows for a basic way to understand the global welfare implications of carbon offsets for developing country agriculture. The objective here is to determine the social optimal production and GHG emission levels simultaneous with the optimal combination of abatement activities and output reduction[17].

Since abatement is negative (net) pollution, MAC(-A) is equivalent to the marginal cost of reducing emissions in developing country agriculture via abatement only, as depicted in Figure 10.2. The marginal abatement cost curve link's emission levels and the cost of additional units of emission reduction. The marginal cost of reducing net emissions via output reduction and abatement simultaneously, termed marginal emissions reduction cost or MERC(S), is derived by adding MNPB (E) and MAC(-A) horizontally at S0 from right to left[18]. Note that MERC(S) is obtained by adding emissions reduction due to less output and emissions reduction due to abatement, analogous to deriving a total supply curve by horizontal summation of two individual supply schedules.

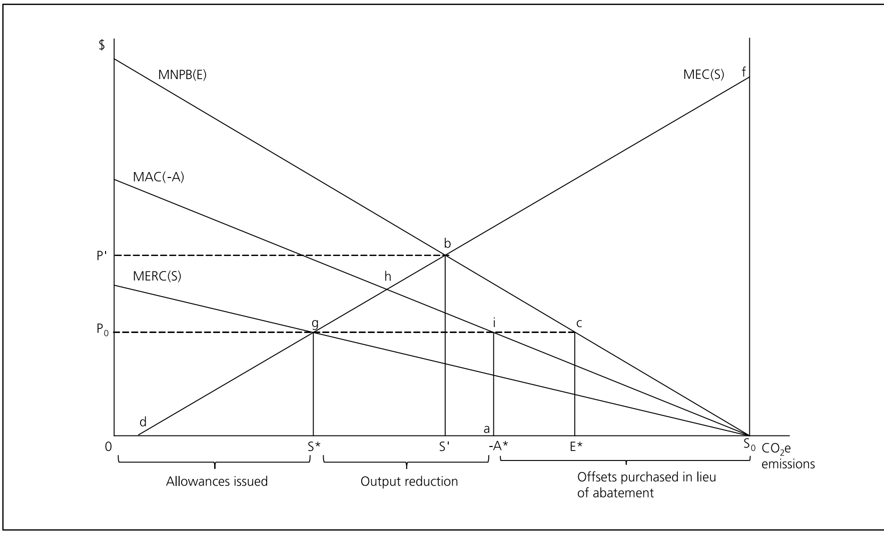
[16]Revenues for methane capture increases the effective price of output, thereby shifting the MNPB curve up in Figure 1 and increasing both output and the optimal level of emissions. Other issues not analyzed here are stacking (summing the value of each non-commodity output that is jointly produced) and the perverse incentive given to firms to overproduce because they are being paid not to pollute (versus tax if it does pollute). In chapter 5 of Baumol and Oates (1988), subsidies for pollution reduction are shown to be inefficient relative to pollution (production) taxes in a dynamic setting due to entry/exit of firms. The 'polluter pay principle' recognizes the possibility that getting paid not to pollute is not the same as taxing farmers when they pollute because of issues related to perverse incentives and exit/entry – see also Spulber (1985) and Ellerman (2008). In addition to deterring exit, de Gorter, Just and Kropp (2008) determine that infra-marginal subsidies can increase output through cross-subsidization. Abatement subsidies to pay farmers how to produce (not what or how much to produce) are decoupled but a farm cannot get paid in some cases without producing and so cross-subsidization can become relevant.

[17]Pearce and Turner (1990) define abatement as yielding only social benefits and are independent of private costs in reducing pollution via output reduction. We adopt this definition for the carbon offset market where regulated firms purchase carbon offsets in lieu of emissions abatement from unregulated countries. Abatement activities are defined as alternative production methods and practices capable of reducing emissions without directly affecting output levels.

[18]Note that the intercept of MNPB(E) on the horizontal axis defines S0, the amount of emissions corresponding to the private optimum without public policy action. The intercept of MAC(-A) on the horizontal axis is arbitrarily set at S0, but could be somewhere to the right of S0 in Figure 2, or in the case of co-benefits with abatement, to the left of S0, thereby increasing the social (and private) benefits from emissions abatement would imply at least some private benefits.

Figure 10.2

Optimal abatement of emissions with carbon offsets for the unregulated sector versus output reduction in the regulated sector



The optimal level of net emissions S* is determined by equating marginal external costs and marginal emission reduction costs. Optimal levels of abatement A* (due to carbon offsets in developing country agriculture in this case) and gross emissions E* defines the optimal level of output reduction (use of allowances in economies with cap and trade in this case) and are determined simultaneously. Abatement in Figure 10.2 is the distance aS0 while output reduction is given by the distance S*a (note that the distance E*S0 must equal the distance S*a)[19]. The price of permits is given by P0 and is equal between regulated economies and developing countries. Allowances can be either auctioned or given to the producing sector (or a combination as proposed in U.S. legislation). There is no difference in which method is chosen in terms of direct economic impact; only the distribution of income is affected.

Area S_0fgS^* below MEC(S) is the optimal reduction in emissions damages, implying that area *dgS** below MEC(S) depicts optimal emissions damages due to net emissions S*. The area S_0gS^* below MERC(S) is the minimum cost of reducing net emissions via an optimal combination of output reduction with permits and

[19]The level of allowances issued in Figure 2 is shown to be less than offsets purchased. This is impossible but think of the vertical axis shifted right arbitrarily for exposition purposes. In reality, offsets are 4 percent of allowances for the EU in 2008 (2.076 billion tonnes of CO2e allowances were surrendered while offsets (the sum of ERU and CER) were 0.082 billion tonnes of CO2e).

abatement with carbon offsets. Area S_0gS^* is equal to the sum of output reduction costs S_0cE^* and abatement costs S_0ia. Hence, area S_0fg depicts the maximum *net welfare gains* of reducing emissions below S_0.

The possibility of carbon offsets through the CDM increases total welfare. Without carbon offsets, the gain in emission reduction is given by area $fbS'S_0$. The social costs would be area $bS'S_0$. The net gain is fbS_0.

But the option of purchasing carbon offsets means fewer allowances are used and so less output reduction occurs in the regulated economies subject to cap and trade but there is more emission reduction overall. The gain in emission reduction is given by area fgS^*S_0 (more than without offsets by the area $gbS'S^*$). Social costs are given by area $cE^*S_0 + iaS_0$ which equals area gS^*S_0. Net social gains are given by area fgS_0. Total gains are higher than without offsets by the area bgS_0.

The equilibrium in Figure 10.2 is a characterization of abatement activities (in developing country agriculture with carbon offsets) and output reduction (in a country with cap and trade through reduced fossil fuel consumption). This framework of analysis provides a basis to analyze the economics of offsets in terms of costs and benefits to each of developing country agriculture and economies with cap and trade.

In reality, cap and trade will also induce firms to invest in abatement technologies (e.g., installing end-of-pipe equipment) and/or to change production practices (e.g., changes in input mix) so there will be a combination of abatement and output reduction in the regulated economies. The MNPB will shift in as a result. Instead of making Figure 10.2 more complex, we can represent the output reduction/abatement combination for cap and trade economies in the bottom panel of Figure 10.1. Consider the increased costs of abatement to be reflected in the new supply curve S' in Figure 10.1[20]. This shifts the MNPB curve left (not shown). The new permit prices before the introduction of carbon offsets is distance BC in the bottom panel of Figure 10.1 (before, it was distance BD equal to P' in Figure 10.2). The analyses of MNPB in Figures 10.1 and 10.2 would be maintained except they would now be inclusive of any abatement activities induced by cap and trade.

Likewise, the marginal abatement curve MAC in developing country agriculture can include the marginal costs of reduced output (or the marginal benefits of increased output should co-benefits from abatement activities result). In this case, the marginal abatement curve MAC can be viewed as the total marginal social costs of abatement and shifts up (down) if there are increased costs (co-benefits) in production.

[20]A very recent paper by Goulder, Hafstead and Dworsky (2009) depict abatement exactly like this which is equivalent to the analysis in Figures 9.2-9.4 in this paper.