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Timothy Laing, Charles Palmer

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‘Economy-wide impacts of REDD when there is political influence’

Corresponding author:

Timothy Laing
Department of Geography and Environment and Grantham Research Institute on Climate Change and the Environment
London School of Economics and Political Science
Houghton Street
London
WC2A 2AE
Email: t.j.laing@lse.ac.uk
Telephone: 07780551902
Fax: +44 (0)20 7955 7412

Other authors:

Dr Charles Palmer,
Department of Geography and Environment
London School of Economics and Political Science

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Abstract

National-level strategies for Reducing Emissions from Deforestation and Degradation (REDD), financed by international transfers, have begun to emerge. A three-sector model is developed to explore the economy-wide effects of two policies, incentive payments and taxes, implemented by a government participating in REDD. Two sectors utilise forest as an input to production, one in which forest is substitutable for labour and one in which forest and labour are complements. The government factors in two opposing types of general equilibrium effect when determining the efficient payment level: one that changes the relative price of forest and one that results from the income transfer related to the payment. Unlike taxes, payments result in unequal income transfers and a shift in relative prices. With political influence, the forest-using sectors may lobby for lower payments in order to create a larger international transfer. REDD may be less cost-effective than envisioned at the international level.

Keywords: REDD, Political influence, General equilibrium, climate change, sustainable forest management

JEL Classification: D50, D72, O13, Q23, Q28, Q54, Q58

1. Introduction

Reducing emissions from deforestation and forest degradation (REDD) in tropical countries could address up to a fifth of global, anthropogenic greenhouse gas emissions. Since Stern (2006), REDD has emerged as a potentially cost-effective strategy for reducing emissions, an argument based on comparing the marginal abatement costs of different mitigation strategies. Despite on-going uncertainty regarding the design of an international REDD mechanism under the United Nations Framework Convention on Climate Change, national-level strategies and policy frameworks are likely to play an important role (Wertz-Kanounnikoff & Angelsen 2009). Indeed, countries are already developing strategies that include REDD. For example, Guyana has instituted its Low Carbon Development Strategy, and the World Bank's Forest Carbon Partnership is involved in developing similar strategies in a number of countries.

Through such strategies, governments can take on responsibility for attracting and harnessing finance, develop and implement REDD policies, and set baselines for emissions reductions. Thus, they allow for the possibility of an economy-wide approach to REDD with a single baseline for emissions across all relevant, forest-using sectors. This could account for the release of carbon embodied in biomass even if it 'leaked' from one sector to another as a consequence of policy implementation.[1] National-level strategies also imply an important role for central governments in the REDD policy-making process. Policies for REDD are likely to be concentrated in

[1] 'Carbon leakage' occurs when policy efforts to control emissions in one place or sector cause emissions to shift to another place or sector that is not subject to the policy (see Murray 2009). It can occur as production, investment or the sourcing of consumption goods is relocated as a result of climate policy.

forest-using sectors. Yet in many tropical countries these are often characterised by weak governance and endemic rent seeking (Amacher 2006; Koyuncu and Yilmaz 2008; Palmer 2005). Introducing international finance for REDD could potentially redirect rent-seeking efforts towards its capture (see Myers 2007). Indeed, corruption has already been reported in early REDD initiatives. For example, Liberian government officials were allegedly bribed by carbon investors to secure carbon rights to a forest concession at below-market values (Financial Times 2010).

In this paper, we develop a model of a small open economy in order to examine the impacts of policies implemented through a national REDD strategy. This serves to address the following three questions. First, what are the economy-wide, general equilibrium effects of implementing REDD? Second, how might these affect government policies for achieving REDD? And third, how do these effects change with political influence from sectors affected by REDD?

Angelsen (2009) groups policies for REDD among four categories: policies that increase and capture the rents from using forests sustainably; policies that reduce the rent from forest-extractive industries; policies that directly regulate land-use; and cross-sectoral policies. In this paper, we consider policies belonging to the first two categories, respectively, incentive payments (or payments of environmental services) along with input and output taxes.[2] Yet all have impacts beyond the sectors directly affected by a given policy. By shifting labour, capital and other inputs between sectors – via shifts in relative prices – REDD will have broader economic impacts. For example, REDD may be used to encourage the growth of sectors that are less directly

[2] Policy options for REDD mirror those of forest conservation more generally (see, for example, Angelsen 2008, Angelsen 2009, Angelsen 2010, Daviet 2009, Palmer 2011, Pfaff et al. 2013), although incentive payments schemes have been central to REDD policy discussions in recent years.

dependent on forest as an input to production. However, input and output prices and the relative profitability of all sectors may also change.

Recent research has begun to address the potential, economy-wide impacts of REDD (see Lubowski & Rose 2013, for a recent review). Of particular relevance to our paper is work which utilises the Computable General Equilibrium approach. For example, Ibarraran & Boyd (2010) examined the multiplier and distributional effects of REDD policies in Mexico. Opening the general equilibrium 'black box', Ollivier (2012) developed a growth model with land-conversion dynamics in a two-sector economy and assessed the long-term impacts of an international REDD transfer. Our model of a multi-sector economy also adopts a national REDD strategy financed by an international transfer. Yet our contribution examines how different policies might affect different sectors, including their use of forest. In this respect, we follow earlier work concerned with the impacts of different policies on deforestation in a general equilibrium setting; for example, Deacon (1995), who examined the impact of transportation improvements, taxes and new employment opportunities on deforestation. In further contrast to Ollivier (2012), we also take into account the potential for political influence on REDD policy making. Specifically, we adopt the common-agency model of Grossman & Helpman (1994), who used it to investigate the impact of lobby group influence on trade policy. It has been widely applied to examine the role of political influence in public policy-making, including environmental taxes and subsidies (Fredriksson 1997), environmental protection (Schleich 1997, Yu 2005) , and forest conservation (Eerola 2004; Jussila 2003). To our knowledge, our paper is the first to apply it to international-level incentives, in particular REDD.

Previous research on policy impacts in a general equilibrium setting illustrated how policies such as taxes shift the relative prices of inputs or outputs, returning revenue on a per-capita basis. By contrast, we show how incentive payments shift the relative price of inputs, and provide a series of (potentially unequal) income transfers to different sectors. Indeed, the size of the shift in relative prices helps determine the level of income transfer. By implication, the international incentive made to a government adopting a national REDD strategy may not be equivalent to the incentive transferred by that government to sectors participating in REDD. Thus, in moving away from some of the idealised conditions for policy implementation assumed in many economic models of REDD, we find that REDD may be less cost-effective than originally envisaged at the international level.

Introduced in Section 2, our model adopts the consumer and producer formulation of Fredriksson (1997) and incorporates three sectors similar to the framework of Jussila (2003). Two sectors use forest as an input to production. In the first, 'agriculture', forest is substitutable with labour and use of the forest produces a carbon externality. In the second, 'sustainable forest management' (SFM), forest is used in joint production with labour, and there is no carbon externality. The distribution of forest between sectors is determined in a market setting. A third sector represents the remainder of the economy.

Inclusion of two, different forest-using sectors enables us to model the fact that tropical forests are not always used in an extractive manner. Recent decades have witnessed growth in the non-extractive uses of forests, which potentially cause little or no deforestation. Such activities include eco-tourism, sustainable forestry and biodiversity prospecting. Earlier work by, for example, Ferraro & Simpson (2002), Groom & Palmer (2010), and Muller & Albers (2004) modelled these activities as joint production. We depart from those models by considering joint production in a general rather than partial equilibrium setting. REDD is arguably likely to be as much about shifting forest to joint production activities as it is about using incentives to set forest aside (e.g. see Angelsen 2010; Palmer 2011). Our model illustrates how forest owners change activities between different productive activities, in response to incentives.

An international incentive is offered to the government of the REDD host country as a payment per unit of carbon externality reduced below a business-as-usual baseline. This could be made by a body such as the FCPF or a country seeking to finance REDD via bilateral arrangements in the mould of those negotiated between Norway and respectively, Brazil, Guyana, and Indonesia.[3] In order to reduce emissions, the government implements a payment scheme. As shown in Section 3, payments are made to both forest-using sectors with the total sum equal to the international incentive. The government then faces a choice of the level or size of payment that it makes to either sector. Its choice helps to determine both the size and the share of the international incentive or 'pie'. Increasing the payment to the agricultural sector strengthens the incentive to reduce forest use in that sector. This helps create a larger pie, a larger share of which is distributed to the agricultural sector. By contrast,

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[3] Similar to many current REDD initiatives these are dependent on public funds. While some REDD projects are financed from the sale of Voluntary Emissions Reductions, carbon markets play a relatively small role compared to public financing initiatives. Yet the development of regional carbon markets that accept credits from REDD, such as California's cap-and-trade system, could boost the future role of markets to finance REDD policy initiatives.

reducing the payment has the opposite effect, reducing both the pie and the sector's share.

We introduce political influence to our model by adopting the common-agency model of Grossman & Helpman (1994), in Section 4. In previous work by, e.g. Fredriksson (1997), Jussila (2003), 'contributions' are paid to the incumbent government, which desires these to aid re-election. The contributions are essentially a valuation by the government of some element of the welfare change of one specific sector over the others in response to a change in policy. This valuation may be monetary or it may be due to preferences inherent in the government for one particular sector. For example, due to interest group lobbying, the political make-up of the country or a perception that protection of a particular sector offers long-term benefits to the country. In our model, giving contributions is conceived as having political influence, which can be offered by either forest-using sector.

When the agricultural sector has political influence, we find that the direction of change in incentives to either sector is indeterminate. It depends on a price effect that represents the adverse impact payments have on the price of forest in that sector ('forest price effect') and an income effect that tends to push up the level of payments to the agricultural sector as it obtains a greater share of the pie created by the incentive ('income transfer effect'). Which of these effects dominates depends on the dependence of the agricultural sector on the forest input, the ease to which agents can switch their activity between sectors, and the deforestation baseline. A similar indeterminate result is found when the SFM sector has political influence. Again, the balance between the price and the income effects determines the direction of change.

This leads to the counter-intuitive result that under some conditions the SFM sector may lobby for a lower payment to its own sector in order to create a stronger incentive to reduce forest use in the agricultural sector and boost the size of the international incentive.

In Section 5, we consider input and output taxes, a combination of taxes and incentive payments, in addition to relaxing the assumption of perfect labour markets. Taxes are shown to influence factor and output prices as well as producers and consumers. In contrast to the payment scheme, the international incentive is added to tax revenue and redistributed on a per-capita basis. This creates a separation between the size of the pie and the share. Similar effects are taken into account by the government when neither sector has political influence. But when the agricultural sector has influence input tax rates are reduced. Tax rates rise when the SFM sector has influence. Our results are robust to relaxing the assumption of perfect labour markets. Section 6 discusses the results before concluding.

2. Model set-up

Production

The majority of countries likely to be recipients of REDD finance can be characterised as small, open economies. Thus, we set up our model in this way. There are three producing sectors, two of which utilise a forest input, f, in production. The first of these sectors, 'agriculture' (β), has two inputs f and labour, l, substitutable using a constant-returns-to-scale technology. In utilizing land under forest cover, the sector produces a negative carbon externality from forest clearance. It thus represents a forest-extractive industry, which varies from place to place, for example, soya or cattle ranching in Brazil, and palm oil in Indonesia.[4]

In the second forest-using sector (γ), 'sustainable forest management' (SFM), forest is an input, again in combination with labour. Following Ferraro & Simpson (2002), this sector is characterised by joint production, i.e. labour and forest are strict complements. Joint production can occur in non-extractive forest-using sectors such as ecotourism, biodiversity prospecting, and non-timber forest product extraction. Relatively undisturbed forest ecosystems are employed as inputs, which are combined with labour to produce an output, e.g. tourist excursions, chemical compounds, or fruits. Thus, use of the forest in this sector does not produce a negative carbon externality, i.e. production occurs without forest clearance.

The third sector is termed industry (α), which acts as a numéraire representing all other production in the economy. It uses a single factor, labour, using constant returns to scale technology and has an input-output coefficient of one.

Goods produced by the three sectors are x_α, x_β and x_γ. Prices, $p_{i\in\alpha,\beta,\gamma}$ are determined on the world market, and are thus exogenously given with $p_\alpha$normalised to one. The economy is populated by N individuals, each of whom has a single unit of labour, with N normalised to one. Individuals have a number of roles in this model. First, they can sell their labour endowment to one of the three sectors ('workers'). Second, they can receive profits from one of the three sectors ('operators'). Third, they can consume goods from all three sectors ('consumers'). Individuals are characterised according to

[4] We note that these land uses may have different environmental implications, although they are analogous for the purposes of our model.

the sector in which their profits are generated, either industry, α, agriculture, β or SFM, γ.

Workers can sell their labour endowment to any sector. An assumed competitive labour market equilibrium implies wages are equated in all sectors, normalised to one.[5] We discuss the implication of relaxing the assumption of competitive labour markets in Section 5. In their role as operators, individuals in the agricultural and SFM sectors switch sectors based on relative profits. Each operator is assumed to have a different relative profit level at which they switch between these two sectors. Thus, switching between sectors occurs as profits in either sector rise or fall. It is assumed that operators are unable to switch between industry and the two forest-using sectors. Similar to Ollivier (2012), we assume that barriers exist such that operators in the latter are fundamentally different from those in industry. Barriers could be, for example, economic, social, geographical or institutional. This assumption allows us to focus on the effects of REDD in two specific ways. First, on the potential of REDD to incentivise the agricultural sector to become less forest intensive and second, in providing incentives to operators to switch from the agricultural to the SFM sector.

All sectors maximise profits, giving the restricted profit function $\pi_i(p_i, \bar{z})$ where $\bar{z}$ is the price of the forest input, f for β and γ. These two sectors derive optimal output y_i^* as the level of output that solves:

$$p_i = \frac{\partial c_i}{\partial y_i} \; for \; i \in \beta, \gamma$$

[5] It is assumed that there is a large enough supply of labour for x_α to be produced in all cases.

where $\frac{\partial c_i}{\partial y_i}$ is the partial differential of the cost function, $c_i(f_i, l_i, \bar{z})$. Given optimal output, the sectors then calculate their level of forest demand f_i and labour demand l_i as the solutions to:

$$\min c_i(f_i, l_i, \bar{z})$$

Next, $\bar{z}$ is determined in a forest market determined by the following operation and timeline:

1. Both sectors observe output prices in their respective sectors.
2. Sectors calculate their level of output, forest and labour demand for each level of $\bar{z}$.
3. A third party then calculates the forest input price $\bar{z}$ based on the requirement that:

$$f_\beta^* + f_\gamma^* = f_t^*$$

where f_t^* is the total amount of forest in the economy. This can be interpreted as the total, state-owned area of forest where production is legally sanctioned, i.e. excluding protected areas, and where production might be profitable. The third party in step 3 is analogous to the concept of a Walrasian auctioneer that acts as an independent party working to clear the market.

The determination of $\bar{z}$ clears all markets and defines optimal output, y_i^*, realised forest input demands, f_i^*, labour input demands, l_i^*, and forest input price, $\bar{z}$. These in turn determine profit levels in each sector and the distribution of operators between sectors.

Our simplifying assumption of perfect forest markets is justified on the basis of our focus on the general equilibrium effects of REDD, driven by changes in relative prices. The forest market also allows for the switching of forest use between sectors. This enables us to determine the incentives to increase the use of forest in a more non-extractive rather than extractive way.

Consumption

Consumers consume all three goods and their utility is an additive function of consumption of the goods, $x_\alpha, x_\beta, x_\gamma$:

$$U_i = x_\alpha^i + x_\beta^i + x_\gamma^i$$

for $i = \alpha, \beta, \gamma$, where x_α^i is consumption of the numéraire and x_β^i , x_γ^i is consumption of each production good.

Consumers are subject to a budget constraint and are assumed to use all income, Y_i, to purchase the two goods.

$$Y_i = x_\alpha^i + p_\beta^*.x_\beta^i + p_\gamma^*.x_\gamma^i \quad (1)$$

where p_β^* is the world market price for x_β and p_γ^* is the world market price for x_γ normalised by the numeraire price.

From equation (1) an indirect utility function, V_i, can be derived:

$$V_i = Y_i + u\left(d_\beta(p_\beta^*)\right) - p_\beta^* d_\beta(p_\beta^*) + u\left(d_\gamma(p_\gamma^*)\right) - p_\gamma^* d_\gamma(p_\gamma^*) \quad (2)$$

where $d_\beta(p_\beta^*)$ and $d_\gamma(p_\gamma^*)$ are the realisations of the demand function for consumers (who are assumed to have identical preferences) at world market prices p_β^*, p_γ^*; $u_i(d(p_i^*))$ is the resulting utility from that demand. The last four terms on the right-hand side of equation (2) thus represent consumer surplus from consumption of the production goods. Given exogenously-determined prices, the values for consumer surplus are fixed and utility is hence a direct function of income.[6]

Income

Income is generated from two sources, labour income and profits. The income of individuals in each sector is thus:

$$Y_i = i + \pi_i \ (3)$$

for $i = \alpha, \beta, \gamma$, where i is the share of population who operate in that sector and represents labour income.[7]

Social welfare, W, is given by the aggregate indirect utility of the population, which follows from equations (2) and (3) as:

$$W = 1 + \pi_\beta + \pi_\gamma + u\left(d_\beta(p_\beta^*)\right) - p_\beta^* d_\beta(p_\beta^*) + u\left(d_\gamma(p_\gamma^*)\right) - p_\gamma^* d_\gamma(p_\gamma^*)$$

We assume that each unit of forest input used in agriculture, f_β, creates one unit of the carbon externality, and $F^* = f_\beta^*$ is the level of forest-based carbon externality in the baseline, i.e. before the implementation of any REDD policy. It is therefore the business-as-usual scenario of carbon emissions generated by deforestation.

3. Introducing REDD

A REDD strategy is implemented by the government of the economy ('the government'). It is offered an international incentive, χ, for reduction in the generation of the forest-related carbon externality below the baseline level, F^*, with $\chi > 0$ and payments of zero for:

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[6] This follows similar assumptions made by Fredriksson (1997).

[7] π_α is a constant that is not impacted by any of the changes in our model. It is therefore excluded.

$$f_\beta^* > F^*.$$

Payment Scheme

The payment scheme consists of a financial transfer to both the agricultural and SFM sectors with the total equal to the payment received by the government. The scheme gives a payment, ρ, to each forest sector given by:

$$\rho_i = \varphi_i(F^* - f_\beta^*), \qquad i \in \beta, \gamma$$

with $\chi = \sum_{i=\beta,\gamma} \varphi_i$ and $\varphi_i > 0$. It is assumed that payments accrue to operators in the agricultural sector.[8]

The payment scheme splits the entire ‘pie’ from the international incentive between the two sectors. Since the size of the pie is dependent on the activity of the agricultural sector it serves to increase the price of forest in this sector. The scheme consists of two parts. First, an income transfer component equal to the payment level multiplied by baseline forest use, F^* and second, an increase in the price of utilising the forest input faced by the agricultural sector. In the SFM sector, the scheme equates to an income transfer equal to the payment to that sector multiplied by the reduction in the carbon externality. Thus, the scheme has the effect of driving a wedge in forest input prices between the two sectors. The payment scheme changes the relative prices of the forest input and redistributes the revenue in proportion to the change in relative prices.

With the payment scheme, the profit function for the agricultural sector is amended to:

$$\pi_\beta' = \pi_\beta[p_\beta^*, \bar{z} + \varphi_\beta] + \varphi_\beta F^*$$

[8] Should payments be given to consumers in β after the production decision is made there will be no effect on quantities of forest input.

The profit function for the SFM sector becomes:

$$\pi_\gamma' = \pi_\gamma[p_\gamma^*, \bar{z}] + \varphi_\gamma(F^* - f_\beta^*)$$

Overall social welfare is:

$$W = 1 + \pi_\beta' + \pi_\gamma' + u\left(d_\beta(p_\beta^*)\right) - p_\beta^* d_\beta(p_\beta^*) + u\left(d_\gamma(p_\gamma^*)\right) - p_\gamma^* d_\gamma(p_\gamma^*)$$

The government's maximisation problem is thus:

$$\max_{\varphi_\beta, \varphi_\gamma} W = 1 + \pi_\beta'[p_\beta, \bar{z}, \varphi_\beta] + \pi_\gamma'[p_\gamma, \bar{z}, \varphi_\gamma, f_\beta^*] + CS$$

Subject to:

$$\sum_{i=\beta,\gamma} \varphi_i = \chi$$

where the constant level of consumer surplus relating to the two production goods is given by:[9]

$$CS = u\left(d_\beta(p_\beta^*)\right) - p_\beta^* d_\beta(p_\beta^*) + u\left(d_\gamma(p_\gamma^*)\right) - p_\gamma^* d_\gamma(p_\gamma^*)$$

We solve the maximisation problem using the Lagrangian method with the government maximising:

$$W = 1 + \pi_\beta'[p_\beta, \bar{z}, \varphi_\beta, f_\beta^*] + \pi_\gamma'[p_\gamma, \bar{z}, \varphi_\gamma, f_\beta^*] + CS + \lambda(\varphi_\beta + \varphi_\gamma - \chi)$$

This gives the first-order conditions of:

$$\frac{\partial W}{\partial \varphi_\beta} = \frac{\partial \pi_\beta}{\partial \varphi_\beta} + F^* + \frac{\partial \pi_\gamma}{\partial \varphi_\beta} - \varphi_\gamma \frac{\partial f_\beta^*}{\partial \varphi_\beta} + \lambda$$

$$\frac{\partial W}{\partial \varphi_\gamma} = (F^* - f_\beta^*) + \lambda$$

$$\frac{\partial W}{\partial \lambda} = \varphi_\beta + \varphi_\gamma - \chi$$

These conditions are rearranged to give the following payments, made to each forest-using sector:

[9] In subsequent discussions of the model we drop CS from the welfare equation as it is a constant and hence, is not affected by policy choices.

$$\varphi_\beta = \chi - \left(\frac{\partial \pi_\beta}{\partial f_\beta^*} + \frac{\partial \pi_\gamma}{\partial f_\beta^*} + \frac{f_\beta^*}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}} \right) (4)$$

$$\varphi_\gamma = \frac{\partial \pi_\beta}{\partial f_\beta^*} + \frac{\partial \pi_\gamma}{\partial f_\beta^*} + \frac{f_\beta^*}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}} \ (5)$$

$$\lambda = -(F^* - f_\beta^*)$$

with the following constraints:

$$0 \leq \varphi_\beta, \varphi_\gamma \leq \chi$$

The bracketed term in equation (4) along with equation (5) represent the general equilibrium effects of the payment scheme. In (4), the amount transferred to the agricultural sector is equal to the international payment minus the general equilibrium effects of implementing the scheme. These effects include the impact on profits of changing the level of forest input in agriculture in both the agricultural and SFM sectors, and a final term representing an income transfer effect.

The payment scheme consists of a fixed level of income transfer dependent on the baseline forest level, and an increase in the forest price faced by the agricultural sector levied at the rate of payment to that sector. Revenues are redistributed according to the size of payments made to the agricultural and SFM sectors. The general equilibrium effects can be differentiated as follows. First, the ‘forest price effect’ allow us to focus on the impacts that result from the payment scheme adjusting the relative price of forest between the sectors:

$$\frac{\partial \pi_\beta}{\partial f_\beta^*} + \frac{\partial \pi_\gamma}{\partial f_\beta^*}$$

The 'income transfer effect' provides a degree of income transfer along with changing the relative forest price:

$$\frac{f_\beta^*}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}}$$

Factoring in the general equilibrium effects resulting from the payment scheme implies a different level of incentive to producers than that envisaged by the country or international body providing the incentive, i.e. based on standard opportunity cost calculations.

The following assumptions are made regarding the direction of the partial derivatives:

$$\frac{\partial \pi_\beta}{\partial f_\beta^*} > 0 \,, \frac{\partial \pi_\gamma}{\partial f_\beta^*} < 0 \,, \frac{\partial f_\beta^*}{\partial \varphi_\beta} < 0$$

It is assumed that an increase in the forest-input demand, f_β^*, in the agriculture sector, *ceteris paribus*, will increase profits. The increase in f_β^* allows greater production thus increasing profit levels with the proviso that the increase in f_β^* will also raise $\bar{z}$. It is assumed that the first of these effects always dominates but at a decreasing rate:

$$\frac{\partial^2 \pi_\beta}{\partial f_\beta^{*2}} < 0$$

An increase in f_β^*, reduces profits in the SFM sector as it both restricts the amount of forest input available in that sector, reducing production, and drives up the forest input price, $\bar{z}$. With joint production technology, the scale of this effect is independent of the level of f_β^*:

$$\frac{\partial^2 \pi_\gamma}{\partial f_\beta^{*2}} = 0$$

An increase in the payment level to the agricultural sector reduces the level of forest input demand in that sector since it increases overall marginal costs, reducing the level of optimal output, y_β^*, as well as increasing the relative price of forest against labour. The latter encourages substitution between the factors for any given level of output. This effect is constant with respect to the payment level:

$$\frac{\partial^2 f_\beta^*}{\partial {\varphi_\beta}^2} = 0$$

Regarding the payment to the SFM sector (equation (5)), an interior solution to the model can be found. The first term is positive and the second and third are negative, which along with the assumption of a payment with a lower-bound value of zero[10], gives an optimum solution if:

$$\left|\frac{\partial \pi_\beta}{\partial f_\beta^*}\right| > \left|\frac{\partial \pi_\gamma}{\partial f_\beta^*} + \frac{f_\beta^*}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}}\right| \quad (6)$$

Equation (6) is more likely to hold the greater the dependence of the agricultural sector on the level of forest input, since this will increase $\frac{\partial \pi_\beta}{\partial f_\beta^*}$. It also raises the absolute level of $\frac{\partial f_\beta^*}{\partial \varphi_\beta}$ thus reducing the term on the right-hand side of equation (6). The condition is also more likely to hold the smaller the impact of a rise of f_β^* on the SFM sector. It depends on the scale of the impact on the forest input price and the impact of this change on the SFM sector's use of forest. Since forest and labour are complementary inputs it can be assumed that output in this sector is relatively inelastic to forest input price changes, making the impact of a change in price relatively small.

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[10] It is not feasible for there to be a negative rate of payments to either sector as that would involve a transfer of income related to the baseline of forest use. It is, however, feasible for a payments scheme to accompany other policies that change the relative prices thus allowing income transfers. We examine the combination of a payment scheme with taxes in Section 5.

If condition (3) holds, payments to the agricultural sector, and thus incentives to reduce forest use, will be greater when: the dependence of the agricultural sector on forest is smaller; the responsiveness of the SFM sector to increases in forest use in agriculture is greater (either through restrictions on forest input to that sector, or through an increase in its price); forest use in agriculture is greater; and, the impact of the payment on reducing deforestation is smaller.

4. Interest group influence

Either of the forest-using sectors, agriculture or SFM, can exert some influence on government decision making above and beyond its level of overall social welfare. In investigating how this influences payment levels, we follow Fredriksson, (1997), who in turn builds on the characterisation of a menu auction problem by Bernhein & Whinston (1986) and the solution to the political equilibrium identified by Grossman & Helpman (1994).

We first assume that a lobby group can offer a certain amount of influence on government decision-making. What is often termed 'contributions' in the literature we characterise more generally as ‘political influence’. The government welfare function, *G*, now becomes:

$$G = W + \mu C_{i \in \beta, \gamma}$$

where *W* is overall social welfare, C_i is the level of influence offered and μ is the relative weight put on influence and overall social welfare by the government. The term μ denotes the degree of lobby group influence on government decision-making. It can represent the extent to which governments make decisions for the good of their entire population versus the extent to which decisions are made to benefit a certain subset of the population, i.e. those with political influence. If $\mu = 0$, then the model is solved in the same way as in Section 3. C_i is assumed to be a continuous, differentiable function on the policy vector *e* populated by the relevant policy variables $\varphi_\beta, \varphi_\gamma, r$ or t.

The model takes the following steps:

- One of the production good sectors has access to and can influence government decision making.
- This influence is valued by the government along with overall social welfare.
- The sector with this access offers the government a menu of levels of influence based on each level of the policy vector *e*.
- The government then chooses its desired realisation of *e* and receives the identified level of influence.

Following Fredriksson (1997), we identify $(\{C_i\}_{i\in\beta,\gamma}, [e])$ as a Subgame Perfect Nash Equilibrium if and only if,[11]

(i) $\{C_i\}_{i\in\beta,\gamma}$ is feasible

(ii) $[e]$ maximises $\mu W + C_i$ on E

(iii) There exists a $e^{-i} \in E$ that maximises $\mu W + C_i$ on E such that $C_i(e^{-i}) = 0$ for $i \in \beta, \gamma$

The model is then solved for the case when either sector attempts to influence government policy making.[12] Following Grossman & Helpman (1994) and

[11] We drop Fredriksson's third condition as we only have one lobby group offering contributions to the government at any one time.

Fredriksson (1997), influence is locally truthful. Therefore, any change in welfare is reflected in a change in influence. The condition for solving the government's maximisation problem is derived as:

$$\nabla W + \mu \nabla W_i = 0$$

where W_i is the welfare of the sector exerting influence on the government. This condition implies that instead of the government imposing the policy instrument up to the point where the marginal benefit to society is zero, it imposes the policy up to the point where a weighted sum of change in social welfare and the influential sector's change in welfare is zero.

Agricultural sector influence

Influence may originate from economic power, the organisation of industry groups, or the ability to offer payments or campaign contributions directly. When the agricultural sector exerts influence the government chooses a level of policy instrument that solves:

$$\nabla W + \mu \nabla W_\beta = 0$$

with the agricultural sector's welfare becoming:

$$W_\beta = \beta + \pi_\beta + \varphi_\beta F^*$$

Totally differentiating W_β gives:

$$\frac{\partial W_\beta}{\partial \varphi_\beta} = \frac{\partial \pi_\beta}{\partial \varphi_\beta} + F^*$$

$$\frac{\partial W_\beta}{\partial \varphi_\gamma} = 0$$

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[12] When both sectors offer contributions the model simplifies to the case where only social welfare is considered since the two sectors are valued equally.

Thus the government solves the following first-order conditions in choosing the payment level:

$$\frac{\partial \pi_\beta}{\partial \varphi_\beta} + F^* - \varphi_\gamma \frac{\partial f_\beta^*}{\partial \varphi_\beta} + \lambda + \mu\left(\frac{\partial \pi_\beta}{\partial \varphi_\beta} + F^*\right) = 0$$

$$F^* - f_\beta^* + \lambda = 0$$

$$\varphi_\beta + \varphi_\gamma - \chi = 0$$

Rearranging yields the following:

$$\varphi_\beta = \chi - \left(\frac{\partial \pi_\beta}{\partial f_\beta^*}(1+\mu) + \frac{\partial \pi_\gamma}{\partial f_\beta^*} + \mu\frac{\partial \beta}{\partial f_\beta^*} + \frac{\mu F^* + f_\beta^*}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}}\right) \quad (7)$$

$$\varphi_\gamma = \frac{\partial \pi_\beta}{\partial f_\beta^*}(1+\mu) + \frac{\partial \pi_\gamma}{\partial f_\beta^*} + \mu\frac{\partial \beta}{\partial f_\beta^*} + \frac{\mu F^* + f_\beta^*}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}} \quad (8)$$

By comparing (4) and (7) and (5) and (8) it can be seen that the government factors in slightly amended indirect effects of the payment scheme when determining the payment level. The impact on profits in agriculture is given greater weight (as $\mu > 0$) while there are two new terms: one relates to how much the size of the agriculture sector changes in relation to an increase in forest input demand, $\frac{\partial \beta}{\partial f_\beta^*}$; and one relates to the income component of the payment scheme, $\frac{\mu F^*}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}}$. The first is positive since we have previously assumed that $\frac{\partial \pi_\beta}{\partial f_\beta^*} > 0$ and $\frac{\partial \pi_\gamma}{\partial f_\beta^*} < 0$, and that individuals switch between sectors according to relative profits.

The increased weight on profits will tend to reduce the payment to the agricultural sector as will the inclusion of influence on switching. By contrast, inclusion of the income component of the payment scheme will tend to increase the payment to the agricultural sector. This reveals a potential dilemma. On the one hand, the agricultural sector prefers a smaller payment in order to reduce the rise in the price of the forest input, with its impact on both profits and the size of the sector. On the other, this sector would gain from a larger payment as it results in a higher income transfer. Thus, the forest price and income transfer effects, identified in the case where there is no political influence, change. Whether the level of payment to the agricultural sector (and thus incentives to reduce the externality from forest use) rises or falls depends on whether or not the forest price effect dominates the income transfer effect.

If the forest price effect is greater, payments to agriculture fall, which reduces incentives to reduce forest input in that sector thus increasing f_β^*. This rise in f_β^* will in turn increase $\frac{\partial \pi_\beta}{\partial f_\beta^*}$. These two effects will offset part of the fall in the payment made to the agricultural sector. But if the income transfer effect dominates, payments to the agricultural sector rise. This increases incentives to reduce forest input, although it is partially offset by the changes to $\frac{\partial \pi_\beta}{\partial f_\beta^*}$ and f_β^*.

Changes in the direction (and scale) of the payment to agriculture when there is political influence thus depend on the size of the forest price effect, the size of the income transfer effect, the offsetting changes to the reactiveness of profit levels to changes in the forest input, and the change in the income transfer effect. To see this, we examine the difference between the level of payment made to the SFM sector, with and without political influence, when there is agricultural sector influence:

$$\widetilde{\varphi_\gamma} - \overline{\varphi_\gamma} = \mu\left(\frac{\partial \pi_\beta}{\partial f_\beta^*} + \frac{\partial \beta}{\partial f_\beta^*} + \frac{F^*}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}}\right) + \left(\widetilde{\frac{\partial \pi_\beta}{\partial f_\beta^*}} - \overline{\frac{\partial \pi_\beta}{\partial f_\beta^*}}\right) + \left(\frac{\widetilde{f_\beta^*}}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}} - \frac{\overline{f_\beta^*}}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}}\right) \quad (9)$$

where tildas refer to terms under agricultural sector influence and upper-bars refer to terms under no influence. The first bracketed term on the right-hand side of (9) shows the forest price and income transfer effects while the latter two terms show the changes in the reactiveness of profit levels to changes in the forest input, and the change in the income transfer effect.

The direction of change in the level of payments to either sector – and thus the level of the international incentive passed through – depends on the balance between the forest price and income transfer effects. If the former are greater, the impacts of reducing payments to agriculture on profit levels and sector size outweigh the reduced income transfer that this entails. If, on the other hand, the latter effect is greater than the former, payments to agriculture and thus incentives to reduce forest input demand will rise.

Welfare will increase in the agricultural sector (by definition), while it must fall in the SFM sector as the new solution is different from the socially-optimal level derived in Section 3. The size of the decline will depend on the direction and scale of the change in payment levels as well as the price and income effects. A higher payment level for agriculture generates positive income benefits but also brings negative price effects, and vice versa.

SFM sector influence

The same trade-off can also be seen when we examine the case when the SFM sector has influence. Following the same methodology as before, the following solution is found:

$$\varphi_\beta = \chi - \left(\frac{\frac{\partial \pi_\beta}{\partial f_\beta^*} + \mu \frac{\partial \gamma}{\partial f_\beta^*}}{(1+\mu)} + \frac{\partial \pi_\gamma}{\partial f_\beta^*} + \frac{f_\beta^*}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}} - \frac{\mu(F^* - f_\beta)}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}} \right) (10)$$

$$\varphi_\gamma = \frac{\frac{\partial \pi_\beta}{\partial f_\beta^*} + \mu \frac{\partial \gamma}{\partial f_\beta^*}}{(1+\mu)} + \frac{\partial \pi_\gamma}{\partial f_\beta^*} + \frac{f_\beta^*}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}} - \frac{\mu(F^* - f_\beta^*)}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}}) \ (11)$$

Similar to when agriculture has influence, the government factors in the amended indirect effects of the payment scheme; compare (10) and (11) to (4) and (5). The government has a reduced influence from the impact of a change in agricultural forest input demand on agricultural profits. It also takes into account the impact of a change in forest input demand in the agricultural sector on the size of the SFM sector. The income transfer component is modified, with the government now concerned about the level of the income transfer to the SFM sector represented by $\frac{\mu(F^* - f_\beta^*)}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}}$.

To determine whether these differences imply a rising or falling payment level to the SFM sector, we derive the differences between the level of payment made when there is SFM influence and that when there is no influence:

$$\dddot{\varphi}_\gamma - \overline{\varphi_\gamma} = -\frac{\mu}{(1+\mu)} \left(\frac{\partial \dddot{\pi}_\beta}{\partial f_\beta^*} - \frac{\partial \gamma}{\partial f_\beta^*} + \frac{(1+\mu)(F^* - \overline{f_\beta^*})}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}} \right) + \left(\frac{\partial \dddot{\pi}_\beta}{\partial f_\beta^*} - \frac{\overline{\partial \pi_\beta}}{\partial f_\beta^*} \right) + \left(\frac{\dddot{f}_\beta^*}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}} - \frac{\overline{f_\beta^*}}{\frac{\partial f_\beta^*}{\partial \varphi_\beta}} \right) (11)$$

where three dots refer to terms under SFM influence and over-bars again refer to terms without influence; $\frac{\partial \gamma}{\partial f_\beta^*} < 0$ as a consequence of our earlier assumption that $\frac{\partial \beta}{\partial f_\beta^*} > 0$.

In (11) as in (7) there is both a forest price effect (made up of changes in the profit level of the agricultural sector, and the degree of switching between the sectors), and an income transfer effect related to the income transfer component of the payment scheme.[13] The direction of change in the payment level will again depend on which effect dominates.

The influence from the SFM sector reduces the importance of the impact of changes in forest on SFM profits. This pushes up the level of payment to agriculture in order to create a greater pie from the international REDD incentive. The inclusion of the sector-switching effect works in the same direction. Yet, the extra focus on the income transfer component to the SFM sector ($\frac{(1+\mu)\left(F^{*}-\widetilde{f_{\beta}^{*}}\right)}{\frac{\partial f_{\beta}^{*}}{\partial \varphi_{\beta}}}$) pushes up the payment to SFM. This reduces the payment to agriculture and overall incentives to reduce forest input in that sector; which effect dominates will help determine the direction of change in the payment to either sector.

Our result leads to the unexpected conclusion that, under certain conditions, the SFM sector may lobby for smaller payments to itself in order to increase the size of the overall pie even though this implies that they obtain a smaller share of the pie. The trade-off faced by the SFM sector is whether to use its influence to increase or reduce the size of its own payment. An increase reduces the incentive to lower the amount of forest in agricultural production and thus the size of the overall pie. A decrease strengthens the incentive in the agricultural sector to reduce forest use thus increasing

[13] In a similar vein as above –changes in $\frac{\partial \pi_{\beta}}{\partial f_{\beta}^{*}}$ and in the tax revenue effect are taken into account. Again they will offset some of the change in the level of payment.

the size of the overall pie. The decision is therefore whether to lobby for a greater share of a smaller pie, or a smaller share of a larger pie.

4. Taxes and the labour market

Input and output taxes

We examine two further policy instruments that a government could implement as part of a national REDD strategy: input and output taxes. Both are lump sum, levied on, respectively, forest use and the produced good in the agricultural sector. Revenues from these taxes are recycled to the whole population on a per-capita basis. Input taxes operate in a similar fashion to the payment scheme in that they drive a wedge between forest input prices in the agricultural and SFM sectors.

Applying input taxes shows that similar general equilibrium impacts are taken into account by the government when determining how much of the international incentive is passed through to operators.[14] Since the government factors the income transfer component of the payment scheme into its decisions, the payment scheme and the input tax are equivalent when there is no political influence. This is due to our assumptions of homogenous consumers and a government that only optimises over aggregate social welfare.

The output tax shows similar characteristics as the other two instruments. It increases with the international incentive, scaled by the impact of output upon the forest input. The impact on profits in the two sectors is taken into account, along with a final term

[14] This finding supports the discussion of the payments scheme as 'input tax' plus income transfers. Formal derivations of all results presented in this section are available from the authors on request.

representing the impact on revenues from the output tax. The output tax shows a conceptual similarity to both the input tax and the payments scheme. How much of the international incentive reaches operators again depends on the size of the general equilibrium effects.

When we consider political influence on taxes we see clear directions of change. The ambiguity found with a payment scheme is absent as the income transfer effect is removed. Since taxes only work on forest prices, the inter-linked income transfer component observed when payments are made is no longer present.

Similar results are found when we extend the model to incorporate a combination of taxes and payments. With input taxes, the tax level imposed is merely subtracted from the international incentive with the same suite of general equilibrium effects factored into decision making as under the case where only one of the instruments is utilised. With output taxes, the tax level is factored into the payment level, scaled by $\frac{\partial y_{\beta}^{*}}{\partial f_{\beta}^{*}}$, the impact of a change in forest level on output. It is factored in alongside the same general equilibrium effects as in the case without the tax.

Regarding political influence, the ambiguities present when payments alone are utilised become less pronounced. Inclusion of either tax makes it more likely that payments to the agricultural sector, and thus incentives to conserve forest, are reduced when that sector has influence. Payments to the agricultural sector are increased when the SFM sector has influence.

Labour market constraints

The presence of perfect labour markets in our model is a strong assumption that is unlikely to hold in many of the jurisdictions in which REDD is and might potentially be implemented. When there is no political influence, relaxing this assumption has two main effects.

First, if we examine the extreme case where labour markets are perfectly rigid, workers are now confined to their individual labour markets. Any changes in demand for labour are realised in terms of changes in wage rates rather than in movements of labour between sectors. Wages are differentiated among sectors. When there is no political influence, wage effects are included alongside other general equilibrium effects. The changes in wage rates in both forest-using sectors are factored in, weighted by the size of the workforce in each sector. Whether the inclusion of these wage rates increases or lowers incentive levels depends on the relative balance of the change in wage rates in the two sectors. If the wage effect is stronger in the agricultural sector than in the SFM sector tax rates will fall, and vice versa.

The second effect emanates from any changes in the scale of derivatives now that the labour input to each of the sectors is fixed. Given the fixed nature of the labour supply, the change in profit levels, and forest use from a change in output levels, may change. Forest use may be more ‘sticky’ as operators are unable to hire more labour to substitute for forest. In this case, all the policy instruments will tend to be set at a lower level, implying that less of the international incentive is passed on to the agricultural sector.

Under political influence the impact of the relaxation of perfect labour markets differs between instruments. For a payment scheme, the sector-switching effect, (i.e. $\frac{\partial \beta}{\partial \varphi_\beta}$), is merely replaced by the change in wage rates. We can safely assume that the sector-switching and wage rate effects have the same sign. However, the scale of the effect may be greater or smaller depending on the characteristics of the production functions of the agricultural and SFM sectors. For taxes, the sector-switching effect drops out and the wage effect is included instead. The same changes of direction in incentives to reduce forest use in agriculture hold either under agricultural or SFM sectoral influence. Finally, when we look at REDD strategy in which a payment scheme and both taxes are utilized, we again see the sector-switching effect being replaced by the commensurate wage effect. In addition, the income transfer effect is smaller since the sector-switching effect drops out thus implying ambiguity in the overall direction of change in incentives.

6. Discussion and conclusion

In this paper, we developed a model that examines the general equilibrium effects of policies implemented for REDD, and how these might change when there is political influence. Such effects help shape the distribution of the costs and benefits of REDD between the two forest-using sectors, agriculture and SFM, which represent an extractive and non-extractive sector, respectively. The effects are present regardless of the policy considered, i.e. whether a payment or tax scheme, both individually and when used in combination. If they are not factored into policy making, then the incentives to reduce extractive forest use (and the associated carbon externalities) could be different from those transferred at the international level to the government.

An efficient REDD policy chosen by a social welfare maximising government is one which factors in general equilibrium effects. This, we find, could raise the marginal cost of the policy. Hence, the full value of the international incentive may not be fully passed through to the relevant sectors if the policies chosen and implemented for REDD have negative economic consequences. Higher international payments would be required to meet an equivalent level of emissions reductions. Accounting for general equilibrium effects therefore implies a move away from the marginal abatement cost concept commonly used to understand and estimate the potential policy costs of REDD. The Stern Review (2006) was the first to make a case for REDD's cost-effectiveness based on this concept. Since then, various analyses have been published, which have come to similar conclusions (see Lubowski & Rose 2013). Our results imply that once we consider the broader economic impacts of REDD, the overall costs of a given REDD policy are likely to rise.

Policies implemented as part of a national-level REDD strategy are likely to have effects beyond forest-extractive sectors such as certain types of agricultural production. They have the potential to shift operators between types of forest use, between sectors, and out of forest-using activities altogether. These shifts are likely to induce changes in output and input prices that may affect the wider economy and either reinforce or weaken the effectiveness of the strategy. A major concern regarding the effectiveness of REDD is leakage. Our model includes an element of 'positive' leakage in the sense of incentivising operators to switch from extractive forest activities to those that utilise forest in a non-extractive manner. Although different goods are produced, we assume that they are identical in terms of utility.

Hence, a switch from agriculture to SFM preserves utility as well as providing carbon savings. Negative carbon leakage, on the other hand, does not occur due to the imposition of a national-level baseline in our model. Yet, it could occur, for example, if a REDD policy encourages production to move to higher-carbon producing sectors or to jurisdictions and economies not participating in REDD. The inclusion of a third forest-using sector into our model with the production of carbon below that of the agricultural sector but above that of the SFM sector could capture the former effect. Incentives that only targeted a particular agricultural sector may encourage a shift in production to this middle sector, which potentially implies fewer carbon benefits from the REDD strategy. A national-level emissions baseline should, however, capture such leakage thus highlighting their importance for effective REDD policy.

The importance of general equilibrium effects is further illustrated when we examine the impacts of political influence from sectorial lobby groups on the payment scheme. Application of the common-agency model to this type of policy instrument, which has the capacity to change relative prices and enact unequal income transfers, is shown to have ambiguous effects irrespective of whether the agricultural or SFM sector has influence. In the former case, forest price effects, relating to increases in the cost of using forest as an input, lead to the agricultural sector preferring lower payment levels. Income transfer effects, related to income transfers under REDD, work in the opposite direction. The balance between the two types of effect will depend on the scale of the emissions baseline used for REDD, and the dependence of the sector on forest for production. This leads to the counter-intuitive result that under certain conditions the agricultural sector may lobby for larger payments if the income effect dominates the price effect.

With an input or output tax, we see more determinate effects. When the agricultural sector has influence tax rates fall; when the SFM sector has influence they increase. This determinacy is a result of the separation between incentives and income distribution that results from our assumption of the per-capita distribution of revenue. It holds when we assume the government implements a tax alongside a payments scheme. Again, there is a separation between the scale of incentives to reduce forest input use in agriculture and the overall distribution of income.

The model developed in this paper is an attempt to address some of the real-world, policy design and implementation issues that have surfaced in previous research undertaken on REDD. It is, however, only a starting point for understanding the broader, economy-wide effects of implementing REDD at the national level, and how political influence might change these. Our attention is focused on two stylised forest-using sectors, and the impacts that REDD policy may have on driving inputs and production between them. The results are robust to the relaxation of perfect labour markets. But the assumption of perfect forest markets is more fundamental to our model. This assumption is unrealistic when applied to the majority of settings for REDD. A key extension to the model would be to relax this assumption, and incorporate a more realistic framework for allocating scarce forest resources between sectors. Future work could also allow operators to move, and relative prices and wages to change.

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