Online Appendices for "Money Growing on Trees: A Classroom Game about Payments for Ecosystem Services and Tropical Deforestation" by Jacobson and Dissanayake

These appendices are:

- Online Appendix I: Suggested Readings
- Online Appendix II: Background Handout
- Online Appendix III: Theoretical Predictions for Community Contract + Illegal Harvest Treatment

Online Appendix I: Suggested Readings to Complement the Game

Most simply, the instructor can distribute the Handout we provide (Appendix II) to give a brief overview of climate change, deforestation, forest-based payments for ecosystem services programs, and the UN-REDD Programme, useful for its brevity and inclusion of many references.

Beyond that, participants can read academic papers on climate change (Angelsen, 2009; McKenney et al., 2004; Stavins and Richards, 2005; Stern, 2006), how deforestation affects climate change (Angelsen, 2008; Bastin et al., 2019; Griscom et al., 2017; Popkin, 2019), programs that fight deforestation (Alix-Garcia and Wolff, 2014; Andam et al., 2010; Angelsen, 2009; Angelsen et al., 2018; Bluffstone, 2013; Bluffstone et al., 2013; Duchelle et al., 2019; Economist, 2010; Lubowski and Rose, 2013; Ostrom, 2010; Senadheera et al., 2019; Sills et al., 2014; Springate-Baginski and Wollenberg, 2010; Toni, 2011; UN-REDD, 2015) or common pool resources and community management (Agrawal et al., 2008; Chhatre and Agrawal, 2009; Ostrom, 1990, 2010). Pattanayak et al. (2010) provide a comprehensive review of studies of payments for ecosystem services programs in developing countries with skeptical conclusions about their de facto effectiveness. In her Nobel Memorial Prize acceptance speech, Ostrom (2010) provides an accessible, broad overview of community governance and common property management. Another useful article is the brief and accessible Jayachandran et al. (2017), which uses a randomized controlled trial to measure the efficacy of a PES program to reduce conserving forest. For short and illuminating discussions of how forest restoration can yield many benefits, including climate mitigation, the *Nature* Perspective by R. Chazdon (2019) and the *Nature* News Feature by Popkin (2019) can be useful. A longer report by the World Resources Institute (Brown, 1998) provides more details on these topics.

A discussion of issues relating the success of payments for ecosystem services programs like leakage, illegal harvest, enforcement, and governance can be very productive and can introduce participants to the practical issues encountered when implementing policies. Resources for such a conversation include Alix-Garcia et al. (2018), Engel (2016), Ostrom (1990), Balooni and Lund (2014), Bluffstone (2013), and Harrison and Paoli (2012). To make enforcement a focus, participants can read recent relevant studies like Duchelle et al. (2014), Honey-Rosés et al. (2009), or Robinson and Lokina (2012) or link back to an older and broader literature on rational crime, going back to Becker (1968). The game also provides a good opportunity to discuss methods to evaluate success of conservation programs and to discuss impact evaluation more generally. Articles that can feed into this discussion include Alix-Garcia et al. (2012), Baylis et al. (2016), Honey-Rosés et al. (2011), Olander et al. (2008), and Shah and Baylis (2015) for both the methods and the applications.

Recent journalistic articles or blog posts about issues of climate change, deforestation and forest degradation, payments for ecosystem services programs, and the UN-REDD Programme can highlight the relevance of these topics in current policy discussions; a quick internet search for news items with these keywords will provide a story that is fresh and relevant. Song (2019), a report by ProPublica, provides an engaging and highly accessible dive into some pitfalls involved with forest-based offsets. The website for the UN-REDD Programme (https://www.un-redd.org/) and the UN-REDD bi-monthly multi-lingual newsletter (https://www.un-redd.org/newsletter-archive) also have a wealth of additional

information on a broad array of topics relating to the UN-REDD Programme. The Ecosystem Services Market Place by Forest Trends (https://www.ecosystemmarketplace.com/) has updated information on PES programs around the world.

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Online Appx II: "Money Growing on Trees" Background: Deforestation & Payments for Ecosystem Services

Over 50% of global forests have been converted to human use since the advent of agriculture (MEA, 2005) and the world has lost 178 million hectares of forests since 1990 (FAO, 2020). Tropical forest area is decreasing at over 10 million hectares per year, with much of the deforestation occurring in developing countries (Bluffstone et al., 2013; FAO, 2020; MEA, 2005; Pan et al., 2011). Forest degradation accounts for about 11% of annual greenhouse gas emissions (IPCC, 2014; Saatchi et al., 2011; Van der Werf et al., 2009).

Restoring forests and preventing forest degradation can help fight climate change. The 2015 Paris climate accord committed signatories to limit "the increase in the global average temperature to well below 2°C above preindustrial levels" and counted countries' efforts to offset their emissions by planting or protecting forests toward emission reduction targets (Griscom et al., 2017; Popkin, 2019). Bastin et al. (2019) find "there is room for an extra 0.8 billion hectares of canopy cover, which would store 205 gigatonnes of carbon," which is about twenty times global annual carbon emissions in 2010 (IPCC, 2014). Curbing deforestation and forest degradation is believed to be a very cost-effective way to address climate change and also support adaptation (Angelsen, 2009; McKenney et al., 2004; McKinsey & Company, 2009; Stavins and Richards, 2005; Stern, 2006).

The United Nation's Framework Convention on Climate Change (UNFCCC) proposed a payment for ecosystem service program, Reducing Emissions from Deforestation and forest Degradation (REDD+), to pay for reduced deforestation and forest degradation with funds from a global carbon market. While the program as initially envisioned never came to fruition due to the lack of a global carbon market, the efforts contributed to the created of the UN-REDD Programme, a joint effort between UNEP, UNDP, and FAO to reduce deforestation and forest degradation (Angelsen et al., 2018; Duchelle et al., 2019; UNFCCC, 2011). There are similar bilateral and multilateral efforts funded by the Green Climate Fund, the World Bank and other countries and entities focused on creating markets to reduce deforestation. Many of these programs are examples of payments for ecosystem services (PES), an incentive-based approach to environmental regulation that is a key part of the policy toolkit for goals like watershed management, reducing deforestation, species preservation, and managing non-point source pollution (Engel, 2016; Engel et al., 2008; Wunder, 2005).

PES programs use a market to connect the receivers of an ecosystem service (a benefit generated by an ecosystem, often public goods like improved air and water quality) to the providers of that service. Global forest-based PES programs create a market for net reductions in greenhouse gas emissions by linking providers of carbon sequestration with countries or entities that are required, or voluntarily choose, to reduce emissions (FAO, 2020; Goldstein and Ruef, 2016). These programs provide incentives for some countries to release less, and sequester more, carbon and for countries that are required to reduce emissions to fund these efforts by purchasing credits (Baker et al., 2019; Bluffstone, 2013; Bluffstone et al., 2013; Rakatama et al., 2017).

Forest-based PES programs may create an opportunity to increase investment in forest management. This investment can bring many benefits, including achieving critical development goals, enhancing forest governance, bolstering global conservation efforts, reducing carbon emissions and deforestation, and contributing to poverty reduction, particularly in communities that manage forests (Andam et al., 2010; Bluffstone et al., 2013; Economist, 2010; Senadheera et al., 2019; Sims and Alix-Garcia, 2017; Springate-Baginski and Wollenberg, 2010; Toni, 2011). As of 2014, about 64 counties were engaged in conducting about 300 pilot forest preservation projects through REDD+ alone (Sills et al., 2014; UN-REDD, 2015) and in 2015, governments and companies committed $888 million in new funding for protecting forests and other carbon-absorbing landscapes (Goldstein and Ruef, 2016).

Community forestry management has generally been considered a successful means to not only to halt deforestation and forest degradation but also to craft institutional mechanisms for equitable benefit sharing in communities. About 25% of forest area in developing country is owned by communities, and this is about three times as much as is owned by the private sector (Agrawal et al., 2008; Bluffstone, 2013; Bluffstone et al., 2013; Chhatre and Agrawal, 2009). Therefore, the successful adoption of forest-based PES in developing countries depends on the effectiveness of these programs in community-controlled settings. Community-controlled forestry requires coordination between community members, but, as discussed by Ostrom (1990, 2010), Bluffstone et al. (2013), and Agrawal et al. (2008), such coordination can be challenging.

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Online Appendix III: Theoretical Predictions for Community Contract + Illegal Harvest Treatment

Let us define f_{oth} as the number of people other than one's-self who engage in illegal harvest.

Then the sequence of actions is as follows:

- Group chooses:
  - PES: No → everyone has CHANGE IN EARNINGS: HV
  - PES: Yes → Group chooses:
    - Police: No → Individuals each choose:
      - Illegal Harvest No → Nature chooses
        - Prob $0.1f_{oth}$ → audited → CHANGE IN EARNINGS: -70
        - Prob $1-0.1f_{oth}$ → not audited → EARNINGS: 50
      - Illegal Harvest Yes
        - Prob $0.1(f_{oth}+1)$ → audited → CHANGE IN EARNINGS: -70
        - Prob $1-0.1(f_{oth}+1)$ → not audited → EARNINGS: 50 + HV
    - Police: Yes → everyone has CHANGE IN EARNINGS: 50-5 = 45

We will now backwards induct from the perspective of a risk neutral person.

If the group chooses to take a payments for ecosystem services contract and not to police, does the person engage in illegal harvest? If we assume that people who are indifferent do not harvest illegally, then a person only engages in illegal harvest if:

$$0.1(f_{oth}+1)(-70)+\left(1-0.1(f_{oth}+1)\right)(50+HV)>0.1f_{oth}(-70)+(1-0.1f_{oth})50$$

Simplifying:

$$0.1(-70)+(-0.1)(50)+\left(1-0.1(f_{oth}+1)\right)HV>0$$

Simplifying further:

$$\left(1-0.1(f_{oth}+1)\right)HV>7+5$$

Which we can solve to: $HV>\dfrac{12}{1-0.1(f_{oth}+1)}$

The greater is f_{oth}, the smaller the denominator and thus the higher the threshold harvest value for engaging in illegal harvest. If $f_{oth}=0$, this value is 12/0.9 = 13.33. In other words, in the range 0-100, only people with harvest values of 0 or 10 would uphold the contract if they thought no-one else was

illegally harvesting. As another example, if a person thinks five people in their group are illegally harvesting, the threshold is 30. Therefore, the equilibrium prediction of the number of people engaging in illegal harvest depends on the distribution of harvest values in the group. If a group of six participants has a random draw of values ranging from 0-100 (but discretely constructed as integers times ten), then we expect a 2/3 chance of each "tens" value appearing; thus it's overwhelmingly likely that there will be some, and in fact quite a bit of, illegal harvest. The rate of illegal harvest can be solved for, but we refrain from doing so because it is not deeply predictive: any given group's set of *HV* draws may vary quite a bit, and, further, risk averse and pro-social people will be less inclined to engage in illegal harvest for a given *HV* and f_{oth}.

If we make a benchmark guess of 50% illegal harvest, then the likelihood of audit in a six-person group is 30%, so a contract without policing yields an expected payoff for illegal harvesters of:

$$0.3(-70)+0.7(50+HV)=14+0.7HV$$

And for those not engaging in illegal harvest of:

$$0.3(-70)+0.7(50)=14$$

Now, given that, if a group chooses to adopt a contract, will they choose to police? If they do, then everyone earns 45. If we take the same 30% audit rate (50% illegal harvest rate) as given, then the expected payoff for any harvest value is never as high as the certain payoff from having a contract and policing it. Thus, in this case, everyone should opt for policing the contract. They will be less likely to do so if they trust each other more, and more likely to do so if they are risk averse.

Given that, will groups choose to accept a payments for ecosystem services contract? If they do, under the baseline inference that contracts will be policed, everyone earns 45. If they do not, everyone earns their harvest value. Thus, group decisions should be the same as in the Community Contract treatment without illegal harvest except that people with harvest value of 50 will cease to be indifference and will prefer to not take the contract.