7 Concurrent green initiatives in Wolong Nature Reserve, China

Hidden spillover effects between the Grain-to-Green Program (GTGP)-like program and the Forest Ecological Benefit Compensation (FEBC) Fund in China are evident in Wolong Nature Reserve in China. Below we present empirical results from a published book chapter by Yang et al. (2016). We first introduce the context setting of Wolong Nature Reserve (also named Wolong National Nature Reserve), then describe data collection and modeling efforts, and finally present findings and implications of the two types of PES programs.

7.1 Wolong National Nature Reserve

Wolong Nature Reserve is located in Wenchuan County, Sichuan Province, in southwestern China, covering a geographic extent of N30º45′–31º25′, W115º42′–115º46′ with a total area of approximately 2,000 km^2 (Figure 7.1). Wolong was designated in 1975 as a flagship reserve to conserve the endangered giant panda (*Ailuropoda melanoleuca*), a global environmental icon that holds nature's value vital to human society (Liu et al., 2001). Wolong lies in the transition zone between the Qinghai–Tibet Plateau and the Sichuan Basin, ranging from 1,200 to 6,250 m above sea level. The climate is warm and temperate, with a mean annual temperature of 8.9ºC and a mean annual rainfall of 995 mm.

Wolong supports a population of 104 giant pandas (Sichuan Forestry Department, 2015), accounting for about 10% of the total number in China. In addition to the giant panda, Wolong is also home to more than 6,000 plant and animal species (He et al., 2008). Over one-third of Wolong's natural landscape is covered by forests, with main vegetation types including evergreen broadleaf, deciduous and coniferous forests, and alpine meadows. These forests provide essential shelter and staple food (e.g., the understory bamboo, *Bashania fangiana*, and *Fargesia robust*) for the wild giant pandas (He et al., 2009) and many other animal and insect species. In 1980, the World Network of Biosphere Reserves under UNESCO's Man and Biosphere Programme recognized Wolong due to its exceptional value for biodiversity conservation. Then in 2006, Wolong was inscribed on the World Heritage List (UNSECO World Heritage Centre, 2006).
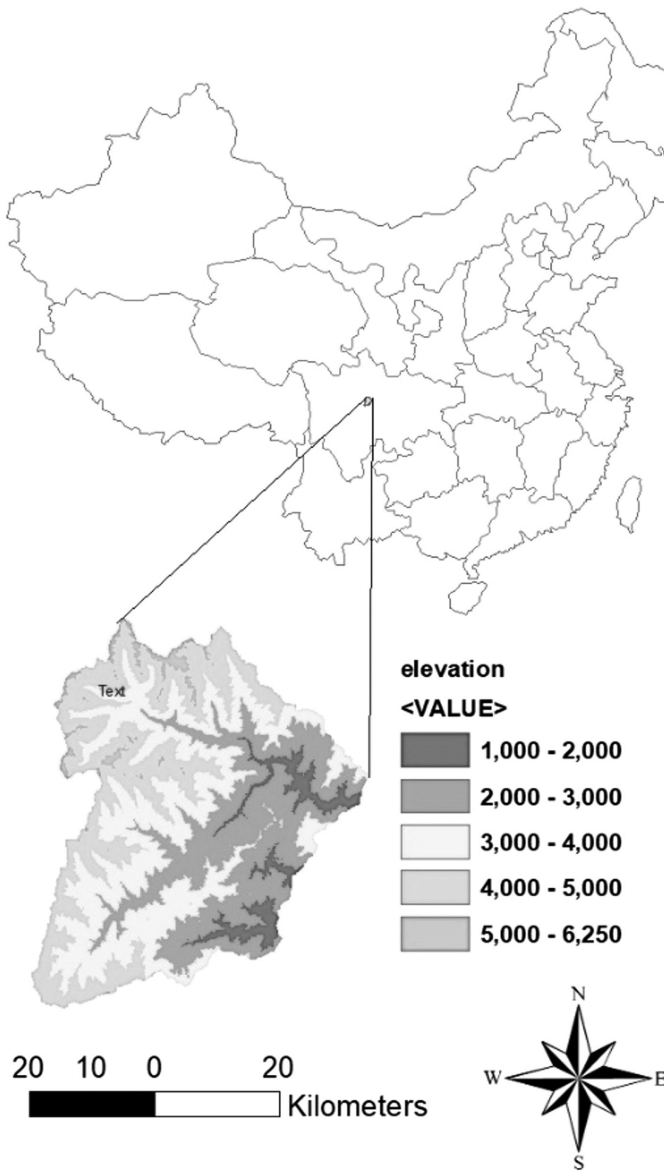
Figure 7.1 Location of Wolong Nature Reserve, China.

Wolong Nature Reserve, comprised of two townships of Wolong and Gengda, is home to nearly 5,000 rural residents. Most of these residents conduct various subsistence socioeconomic activities such as land cultivation, livestock raising, and fuelwood collection. Local livelihoods rely mostly on forest resources such as fuelwood as the primary energy source for cooking human food and pig fodders and heating during the winter. Thus, these human activities are fundamental drivers of ecosystem degradation, potentially threatening the giant panda in Wolong (Viña et al., 2007).

Around 2001, the reserve implemented the Natural Forest Conservation Program (NFCP) and the Grain-to-Green Program (GTGP) (Yang et al., 2013a). In Wolong, the NFCP annual payment rate ranged from 800 to 1000 yuan per household (or US $97.6–121.9, US $1=8.2 yuan in 2001). Households who participated in the GTGP received 240 yuan (US $29.3) per year by converting one mu (1 mu=1/15 ha) cropland into the forest during the compensation years. With a resemblance to the GTGP, the Wolong government developed and implemented a local PES program named the Grain-to-Bamboo Program (GTBP). The GTBP pays residents cash to convert croplands to bamboo plantations, intending to restore the habitat and provide more stable food for the giant pandas (Yang et al., 2013b). Compared to the GTGP, the GTBP has a much higher annual compensation rate, ranging from 900 to 1200 yuan (or US $109.7–146.3) per mu, as it targets croplands in flatter areas with higher opportunity costs. Since GTGP and GTBP have the same goal and implementation method, they are combined as the Grain-to-Green/Bamboo Program (hereafter referred to as GTGB, 2001–2010) (Yang et al., 2016).

7.2 Data collection

Researchers used panel data collected from several rounds of household interviews from 1999 to 2010 (An et al., 2002; Yang et al., 2016; Yang et al., 2013b), with the first round conducted in the summer of 1999. An et al. first obtained the 1996 Chinese agricultural census list and then adopted the stratified random sampling to draw 220 households (about 23% of the household population) from six villages in the reserve based on the list. They also collected demographic and socioeconomic information through face-to-face interviews (An et al., 2002).

In 2002, 2007, and 2009, researchers conducted household interviews to collect similar information for 200, 192, and 207 households, respectively (Yang et al., 2016; Yang et al., 2013b). For all the four household interview sessions, a total of 179 households were consistently interviewed, making up the final sample for the panel data. Since income was of primary interest, retrospective data on household income and expenditure were collected every year from 1998 to 2009 during the household interviews. In the 2007 and 2009 surveys, supplemental questions about the three PES programs (i.e., NFCP, GTGP, and GTBP) included asking for information about payments received by each surveyed household and their perception of the programs. All monetary measures, such as income and expenditure, were deflated according to the 2000 consumer price index (Yang et al., 2016).

7.3 Data analysis and modeling

According to our definition, Yang et al. investigated economic transformation among local households in Wolong under GTGB and NFCP, two concurrent programs. Individually, Yang et al. examined the association between household income growth from 1998 to 2007 and household payments (Yang et al., 2016). The hypothesis sought to explain income growth through relationships to factors representing macro-socioeconomic conditions and household-level characteristics. Macro-socioeconomic conditions refer to the effects of the two PES programs and other policies. Household-level factors were represented by the household's access to different forms of capital, including financial, human, natural, built-up, and social capitals. The dependent variable and explanatory variables are summarized in Table 7.1.

The general regression model can be written as:

$$Y = \alpha + \beta_1 P_1 + \beta_2 P_2 + \gamma C + \delta D + \varepsilon \qquad (7.1)$$

where Y is a vector of household income growth from 1998 to 2007, calculated by subtracting total income in 1998 from total income in 2007. P_1 is a vector of policy intervention, represented as the amount (or percentage) of annual payment received by, or the participation status of, each household in the programs. P_2 is a vector of interactions between the programs. C is a vector of variables reflecting households' access to the five forms of capitals (Table 7.1). D is a contextual variable controlling for regional differences between the two townships (Wolong and Gengda). Regarding the parameters, α is the intercept, while β_1, β_2, γ, and δ capture the fixed effects of the vectors of programs, interactions of the programs, capital access, and contextual factor, respectively. Finally, ε is the error term assumed to be normally distributed with a mean of zero and constant variance.

7.4 Findings and discussion

Although not directly addressing potential spillover effects between the two concurrent PES programs, the regression results (Table 7.2) provide implicit evidence of their interacting effects in Wolong. We found that the GTGB (or the NFCP) payment as part of the total household income had a statistically significant negative impact on household income growth from 1998 to 2007 when considering the program alone controlling other factors. For instance, with each 1% increase in NFCP income, household income growth from 1998 to 2007 decreased by 1280 yuan when controlling for other factors. Similarly, a 1% increase in GTGB payment percentage in total income resulted in a decrease in income growth by 150 yuan.

Surprisingly, the interaction of NFCP and GTGB (i.e., GTGB payment percentage in total income × NFCP payment percentage in total income) had a positive impact on the above income difference (Yang et al., 2016). To better understand

Table 7.1 Description of income growth and explanatory variables at Wolong, China

Variable	Description	Mean	Std. dev.
Dependent variable			
Income growth	Difference in total household income in 2007 subtracting total household income in 1998 (1,000 yuan)	21.988	27.286
Policy variable			
NFCP payment	Amount of annual payment received from NFCP (1,000 yuan)	0.948	0.183
NFCP percentage	Percentage of annual payment received from NFCP in total household income in 2007	6.5%	6.0%
GTGB payment	Amount of annual payment received from GTGB (1,000 yuan)	2.888	2.320
GTGB percentage	Percentage of annual payment received from GTGB in total household income in 2007	16.0%	15.3%
ESP subsidy	Amount of initial subsidy for electricity consumption received from ESP (1,000 yuan)	0.086	0.104
ESP percentage	Percentage of initial subsidy for electricity consumption received from ESP (1,000 yuan)	2.7%	4.1%
TDP participation	Household participation status in tourism business (1 = participated; 0 = did not participate)	0.274	0.447
Financial capital			
Initial total income	Total household income in 1998 (1,000 yuan)	6.285	4.932
Initial percentage of agricultural income	Percentage of agricultural income in total household income in 1998	63.0%	31.3%
Change in agricultural income	Difference in household agricultural income in 2007 subtracting household agricultural income in 1998 (1,000 yuan)	7.817	15.393
Human capital			
Number of labor	Number of laborers in household	2.820	1.455
Change in number of laborers	Difference in the number of household laborers in 2007 subtracting the number of household laborers in 1998	−0.727	1.795
Education	Education level of the most educated non-student adult in 2007 (year)	7.120	3.432
Natural capital			
Cropland area	Total area of cropland in 2007 (mu, 1 mu=1/15ha)	10.450	4.163
Built-up capital			
Distance to the main road	Euclidean distance from household location to the main road (km)	0.431	0.629
Social capital			
Social ties to local governments	Whether the household had an immediate relative member working in local governments or government enterprises (1 = yes, 0 = no)	0.120	0.326

Notes: NFCP: Natural Forest Conservation Program, i.e., one component of the Forest Ecological Benefit Compensation (FEBC) Fund; GTGB: Grain-to-Green/Bamboo Program; ESP: Electricity Subsidy Program; TDP: Tourism Development Program; N/A: not available. The results are from Yang et al. (2016).

Table 7.2 Regression results from Wolong, China

Variable	Coefficient	Robust SE
Policy variables		
NFCP percentage	−128.811***	35.194
GTGB percentage	−15.535**	7.707
ESP percentage	63.921**	28.004
TDP participation	5.274*	3.188
NFCP percentage × GTGB percentage	387.458***	89.473
NFCP percentage × ESP percentage	−188.653	133.730
NFCP percentage × TDP participation	−228.758**	98.906
Financial capital		
Initial total income	−0.175	0.294
Change in agricultural income	1.114***	0.251
Human capital		
Number of labor	2.767**	1.283
Change in number of labor	2.161**	0.977
Education	0.119	0.407
Natural capital		
Cropland area	−1.451**	0.578
Built-up capital		
Distance to main road	−1.783***	0.563
Social capital		
Social ties to local governments	0.319	3.919
Contextual factor		
Township	4.253	2.671
Constant	14.601***	2.788

Notes: *$p<0.10$; **$p<0.05$; ***$p<0.01$. The regression results stand for the effects of concurrent PES programs (NFCP and GTGB) and other control variables on changes in total household income from 1998 to 2007 at Wolong, China (Yang et al., 2016).

the interaction effects, we use an example to illustrate how one PES program may affect income growth through the other PES program. Given a household with a mean value of GTGB payment percentage in total household income (0.16), the conditional effect of 1 unit (i.e., 1%) of NFCP payment percentage on income growth depending on the value of GTGB payment percentage is [(−128.8 + 387.5 × 0.16)/100]=−0.6681772 (unit: thousand yuan). With every additional 1% NFCP payment percentage in total income, combined with the 16% GTGB payment percentage in total income, it would cause overall income growth to decline by 668.1772 yuan.

The conditional effects of NFCP (or GTGB) payment share in total income are affected by GTGB (or NFCP) payment shares of total income. Based on the plots (Figure 7.2), the conditional NFCP effect remains negative when the GTGB payment share of total income is below 0.33, but it becomes neutral (or positive) when the GTGB payment share reaches (or exceeds) the threshold. Simultaneously, the conditional GTGB effect, when interacting with the NFCP effect, would flip from negative to positive if the NFCP payment share in total income increases beyond 0.04.
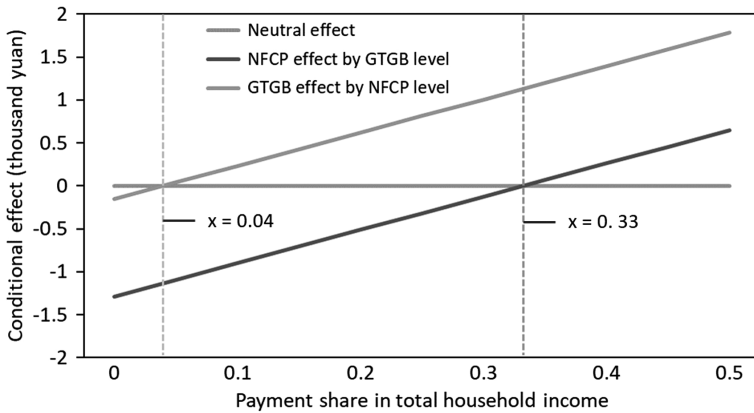
Figure 7.2 Combined effects of NFCP and GTGB on household income difference by different NFCP or GTGB payment shares of total income. The right dash line denotes the threshold (0.33) of GTGB payment share in total income where the total NFCP effect becomes zero; the left dash line denotes the threshold (0.04) of NFCP payment share in total income where the total GTGB effect becomes zero.

The derived effects under the scenarios of single policy and concurrent policies represent the hidden linkages due to the simultaneously implemented programs. Each of the two PES programs alone has a negative effect on income growth, but their synergistic effect is positive, more robust than each individual effect. This surprising outcome may result from households' livelihood changes in adaptation to the implementation of the policy. Under the scenario of GTBP only, "transformative" changes are likely to happen as households shift their livelihoods from farming work to non-agricultural activities, such as rural-to-urban migration, featuring *Policy–Behavior* and *Behavior–Behavior* spillover effects. Thus, households seek non-agricultural opportunities, bringing an economic return to compensate for the reduced income from farming land. Under the NFCP only, household livelihoods tend to experience "incremental" changes, intensifying agriculture by growing more cash crops and using more fertilizer or pesticides. This change characterizes an internal *Policy–Behavior* effect. Compared to alternative livelihood activities such as local off-farm work and migration, the agricultural intensification may contribute less to the total household income growth in the long term since agricultural outputs (e.g., crops) are less lucrative for income but primarily for self-consumption.

The ecosystem outcomes under Behaviors 1 and 2 were not directly addressed in Yang et al.'s (2013) work, and there is evidence elsewhere showing both are positive (Viña et al., 2007). Goals 1 and 2 are similar since both refer to enhanced forest cover and panda habitat quality, except that the latter should be more significant as local villagers switched to non-agricultural activities. Considering the
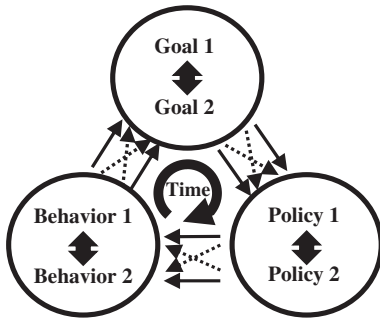
Figure 7.3 Cross-program spillover effects at Wolong, China. The diagram is modified from Figure 1.3, where the solid one-way arrows stand for internal influences from one element to another within the same initiative while the dashed one-way arrows and double two-way arrows for potential spillover effects; the circular one-way arrow represents Time–Time spillover effects. The shaded arrow represents the spillover effect with evidence from this section.

Goal–Policy spillover effect, how changes in ecosystems may feedback into the concurrent payments of NFCP and GTGB is unclear and needs more in-depth analysis. Furthermore, NFCP payments were renewed in 2008 for another 10 years, and GTGB payments ceased in 2010, which complicated the policy effects and made uncovering the hidden linkages more needed.

7.5 Summary

GTGB and NFCP, when implemented alone, each impeded the growth of household income from 1998 to 2007. However, they positively impacted this income growth when applying to the two payments together (Figure 7.3). This surprising outcome is likely due to changes in livelihood strategies: local farmers switched from agricultural intensification (Behavior 1) to out-migration (Behavior 2), substantially reducing or even abandoning farming activities. This *Behavior–Behavior* spillover effect may not be apparent when evaluating each PES program in isolation.

References

An, L., Lupi, F., Liu, J., Linderman, M. A., & Huang, J. (2002). Modeling the choice to switch from fuelwood to electricity: Implications for giant panda habitat conservation. *Ecological Economics*, *42*(3), 445–457.

He, G., Chen, X., Beaer, S., Colunga, M., Mertig, A., An, L., Zhou, S., Linderman, M., Ouyang, Z., Gage, S., Li, S., & Liu, J. (2009). Spatial and temporal patterns of fuelwood collection in Wolong Nature Reserve: Implications for panda conservation. *Landscape and Urban Planning*, *92*(1), 1–9.

He, G., Chen, X., Liu, W., Bearer, S., Zhou, S., Cheng, L. Y., Zhang, H., Ouyang, Z., & Liu, J. (2008). Distribution of economic benefits from ecotourism: A case study of

Wolong Nature Reserve for Giant Pandas in China. *Environmental Management*, *24*(6), 1017.

Liu, J., Linderman, M., Ouyang, Z., An, L., Yang, J., & Zhang, H. (2001). Ecological degradation in protected areas: The case of Wolong nature reserve for giant pandas. *Science*, *292*(5514), 98–101.

Sichuan Forestry Department. (2015). *The fourth survey report on giant panda of Sichuan*. Sichuan Science and Technology Press.

UNSECO World Heritage Centre. (2006). *Sichuan giant panda sanctuaries*. https://whc .unesco.org/en/list/1213/

Viña, A., Bearer, S., Chen, X., He, G., Linderman, M., An, L., Zhang, H., Ouyang, Z., & Liu, J. (2007). Temporal changes in connectivity of giant panda habitat across the boundaries of Wolong, China. *Ecological Applications*, *17*(4), 1019–1030.

Yang, W., Dietz, T., Liu, W., Luo, J., & Liu, J. (2013a). Going beyond the Millennium Ecosystem Assessment: An index system of human dependence on ecosystem services. *PloS One*, *8*(5), e64581.

Yang, W., Liu, W., Viña, A., Luo, J., He, G., Ouyang, Z., Zhang, H., & Liu, J. (2013b). Performance and prospects of payments for ecosystem services programs: Evidence from China. *Journal of Environmental Management*, *127*, 86–95. https://doi.org/10 .1016/j.jenvman.2013.04.019

Yang, W., Lupi, F., Dietz, T., & Liu, J. (Jack). (2016). Dynamics of economic transformation. In J. Liu, V. Hull, W. Yang, A. Viña, X. Chen, Z. Ouyang, H. Zhang. (Eds.), *Pandas and people: Coupling human and natural systems for sustainability* (pp. 109–119). Oxford University Press.