Unintended Land Use Effects of Afforestation in China

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Abstract

The aim of China's Grain for Green Program is to reduce soil erosion by subsidizing reforestation of highly erodible farmland. The program targets cropland on steep slopes with low productivity so that reductions in erosion do not impair food self-sufficiency goals. Theoretical analysis shows that the incentives created by the program combined with insufficient oversight can lead to afforestation of highly productive farmland on level ground. Econometric analysis of a unique land transition data set shows that this unintended land use effect has been substantial, amounting to nearly one-fifth of the total amount of cropland converted to forest. The unexpected land displacement documented here represents a previously unexplored form of leakage in payment for ecosystem services (PES) programs.

Keywords. afforestation, land use, food security, slippage, payment for environmental services, Grain for Green, China

1 Introduction

Payment for Ecosystem Services (PES) programs are increasingly seen as an attractive means of combatting environmental degradation. They have been shown to provide regional public goods such as hydrological services and erosion control (Alix-Garcia and Wolff, 2014). At the same time, they can alleviate poverty by making provision of environmental services economically desirable for low income land users (Wunder, 2005; Van Hecken and Bastiaensen, 2010). While attractive on political and equity grounds, PES programs are known to be prone to implementation problems, especially in developing countries where governance tends to be weak and monitoring of compliance with program restrictions tends to be poor (Pattanayak et al., 2010; Alix-Garcia and Wolff, 2014). This paper uses China as an example to illustrate an unexplored form of land displacement in PES programs that is likely to happen in developing countries. Specifically, it shows that China's afforestation program targeting highly erodible farmland caused by deforestation may mis-target highly productive farmland with low degradation risk.

Deforestation has been an important contributor to numerous environmental problems in China, most notably soil erosion, which results in land degradation, sedimentation of rivers, downstream flooding, and other problems (Lal, 2003; Long et al., 2006; Feng et al., 2010; Cao et al., 2011; Deng et al., 2012; Zhao et al., 2013). A significant share of that deforestation was driven historically by China's ongoing aim of achieving a sufficient food supply. More recently, the Chinese government has engaged in a massive effort to reconvert much of that deforested land back to forest. Specifically, the Chinese government launched a program commonly known as "Grain for Green" (GfG) that pays farmers to convert highly erodible cropland on hillsides to forest. GfG is one of the largest PES programs in the world and has been successful in reforesting large amounts of land: since 2000, forested land area increased by almost 18%, corresponding to average annual increases of 1.2% (FAO, 2015).

The GfG Program planned to reforest nearly 15 million hectares of highly erodible cropland by 2010, which is almost equivalent to the US Conservation Reserve Program (CRP) (Uchida et al., 2005). It targets cropland on hillsides and other cropland at high risk of degradation. However, the program may have the unintended effect of creating incentives to afforest highly productive cropland at low risk of land degradation. Such excess land conversion is problematic for China, which places a high value on being largely self-sufficient in food production. This paper uses a theoretical model and a rich dataset to examine the extent to which China's GfG Program has had such unintended land use effects.

I develop a conceptual framework explaining the conditions under which it is optimal for local officials to use the GfG Program to subsidize afforestation of high productivity farmland, contrary to the intended purpose of the program. Decentralization reforms enacted in China in the early 1980s gave local governments more power and autonomy to execute policies from the central government. Fiscal reforms enacted at the same time gave local governments strong incentives to shift land to higher value uses (Lichtenberg and Ding, 2008). I use a model of local officials' land use decisions to derive the conditions under which GfG subsidies make it optimal to convert high productivity cropland to forest. The analysis indicates that such unintended land conversion is more likely to occur in areas where the productivity of higher quality cropland is low relative to GfG subsidy levels, where the value of forested land is relatively high, and where local government have few alternative sources of revenue.

I investigate the extent to which this unintended land conversion occurs using a unique panel dataset containing confidential county-level records of land transitions and combined with socioeconomic data from county statistical yearbooks. The GfG Program started as a pilot program in 1999. It was phased in gradually over the next 3 years until it was implemented nationwide in 2002. The data included a period (1996-2003) prior to the program, extend through the gradual rollout of the program, and continue into the aftermath of program implementation. I use a difference-in-difference (DID) strategy, with county and year fixed effects to control for unobserved heterogeneity. Two falsification tests (estimating differences in time trends in treated versus un-treated provinces in the pre-treatment period and a placebo test re-estimating the DID model over the pre-treatment period) indicate the common trend assumption is valid.

The preliminary results indicate that unintended conversion of high productivity, low degradation risk cropland was substantial, amounting to nearly one-fifth of the total amount of cropland converted to forest. A robustness check with a share-change model suggests that unintended conversion of high productivity/low degradation risk cropland amounted to about

8% of the pre-program stock. As predicted by the theoretical conversion of low degradation risk cropland was greater in areas where crop productivity was low relative to reforestation subsidies. The estimated breakeven level of cropland productivity for reforestation is higher for high productivity, low degradation risk cropland than for highly erodible cropland, indicating that some high productivity, low degradation risk land was converted to forest while highly erodible land remained in cultivation. In other words, relatively low income farmers with good quality cropland were allowed to enroll in the program. This finding is consistent with the argument that goals of poverty alleviation may dominate environmental goals in PES programs in developing countries (Wunder et al., 2008).

In terms of implications for understanding China's system of governance, the extent to which this unintended cropland conversion occurs suggests that local officials exercise a significant amount of discretion in implementing national policies. The central government relies largely on reports from local officials to monitor how its policies are being carried out, engaging in independent verification only sporadically. Local officials thus appear to have a significant amount of latitude in setting priorities. In the case of the GfG Program, bolstering local government finances with reforestation subsidies appears to have taken precedence over central government directives to preserve farmland at low risk of degradation in order to meet the country's stated food self sufficiency goals.

More generally, this paper is the first to document a previously unexplored form of unintended land use effect of PES programs. Mis-targeting, i.e., enrollment of undesired land, is not uncommon in PES programs. Displacement of deforestation or cultivation due to enrollment (leakage or slippage) has been documented in PES programs aimed at highly erodible cropland in the US (Wu, 2000; Wu et al., 2001; Fraser and Waschik, 2005; Roberts and Bucholtz, 2005; Lubowski et al., 2006; Lichtenberg and Smith-Ramírez, 2011) and at land threatened by deforestation in developing countries (Ewers and Rodrigues, 2008; Alix-Garcia et al., 2012; Arriagada et al., 2012). Most studies have been concerned with the possibility that PES programs might displace deforestation or other forms of land degradation (leakage or slippage), offsetting some of the deforestation or other environmental benefits achieved. In this paper, I show the opposite - that PES program can enroll land whose benefits in alternative uses outweigh the environmental benefits achieved from conversion. This finding underscores the importance of independent monitoring for verifying compliance with PES restrictions and goals.

2 Literature Review

2.1 Unintended Land Use Consequences in PES Programs

Using subsidies to compensate agents for creating positive externalities is relatively straightforward in theory but challenging in practice, especially in developing countries (Pattanayak et al., 2010). Current PES programs in developing countries are often not cost-effective because of mis-targeting (Pfaff et al., 2007; Alix-Garcia and Wolff, 2014). Policy makers tend to promote PES as an instrument for both environmental protection and poverty alleviation, because forest cover and poverty are tightly connected worldwide (Landell-Mills et al., 2002; Turpie et al., 2008; Lipper et al., 2009; Rios and Pagiola, 2010). Despite the tradeoff between poverty alleviation and ecological conservation, the practice of PES is difficult to apply in developing countries because of the governance challenges. The government and market institutions in developing countries are relatively weak, and governmental PES programs are not cost-effectiveness in achieving side objectives such as poverty alleviation and regional development (Wunder et al., 2008; Pattanayak et al., 2010).

In addition to the inefficiency caused by multiple goals, many PES projects face both negative and positive unintended consequences. As Sills et al. (2008) conclude, the failures of PES include encouraging additional conservation or deforestation in areas not under contract. Both types of these unintended spillovers are caused by the displacement of forest exploitation known as leakage or slippage (Wu, 2000; Wu et al., 2001; Fraser and Waschik, 2005; Roberts and Bucholtz, 2005; Lubowski et al., 2006). Although slippage leads to production displacement (substitution slippage; see, for instance, Alix-Garcia et al., 2012; Lichtenberg and Smith-Ramírez, 2011; Arriagada et al., 2012) or changing production incentives on unenrolled land (price slippage; see, for instance, Murray et al., 2004; Robalino, 2007), it may generate positive spillovers.

The possibility of positive spillovers helps to discourage additional deforestation or encourage afforestation (Pfaff and Robalino, 2012), yet to date, there is little empirical evidence on such positive spillovers. Some exceptions include studies of slippage related to the US Conservation Reserve Program (CRP) suggest that it helps to increase production on neighboring lands (Fleming, 2010), increase farmland values (Wu and Lin, 2010), and shift non-conservation uses to later periods (Jacobson, 2014). Positive spillovers are usually considered as a mitigation of slippage, and are assumed to be caused by increased law enforcement (Pattanayak et al., 2010).

Whether the positive spillovers provide additional conservation or induce more problems may vary by country. Studies have argued that the additional forested area, such as afforestation on low degradation risk farmland on level ground, may not yield additional environmental services. Additional hectares of land-use change will only deliver services when the changes are of appropriate quality and location (Pattanayak and Butry, 2005; Sills et al., 2006). More importantly, the unintended conversion of productive farmland to conservation uses can bring more problems in countries with a scarcity of arable land like China, which could have important effects on self-sufficiency in food production.

This paper helps to broaden the literature by showing that land use changes viewed as "positive spillovers" in developed countries like the United States may have negative consequences in developing countries. Countries with scarce arable land relative to its population have legitimate concerns about food security. Additional conservation that jeopardizes farmland with good quality is no longer a "positive" spillover but rather threatens the goals of food self-sufficiency. Excess spending on subsidies reduces program's cost-effectiveness, because additional conversion of low degradation risk farmland yields little environmental benefit. I show theoretically and empirically that unintended leakage in the GfG Program can result in conversion of farmland with low degradation risk on level ground while leaving highly erodible farmland in production, undermining both food self-sufficiency goals and the ecological purpose of the PES program. In such cases, so-called "positive" spillovers worsen rather than mitigate the slippage effects.

2.2 Background of the Grain for Green Program

China had very weak forest policies from 1949 to 1998, because forests were viewed as uncultivated farmland and timber was viewed as cheap raw material for industrial production (Delang and Yuan, 2015). With only 0.08 hectares of arable land per person (in comparison to the world average of 0.20 hectares; see World Bank, 2012), a central goal of the government (embodied in its basic national policies) has always been to remain self-reliant in crop production.[1] To feed the burgeoning population and industrialize the nation, China undertook massive deforestation beginning in the Great Leap Forward period (1958-1962), with the loss of 38 million hectares of forestland and wetland transformed into farmland by 1979 (Du, 2002; Feng et al., 2005). Farming on steep slopes was common due to the oversupply of on-farm labor, who had no off-farm labor market opportunities and aggressively sought new cropland in hilly areas. This resulted in reclamation and degradation of ecologically sensitive patches on steep slopes (Delang and Yuan, 2015).

There was no Forest Law in China until 1978, when China began to realize that it had a "supply and demand crisis due to insufficient reforestation" (Richardson, 1990).[2] Although some traditional forest land was not very fertile and prone to erosion when used for crop production, farmers and local officials had an insufficient incentive to reforest since they could not capture for themselves most of the benefits of reduced erosion (e.g. protection of water-

[1] Preserving farmland is one of the seven basic national policies in China, which is regulated in the Land Administration Law.

[2] The Forest Law was officially promulgated in 1984 to formalize the ownership of trees and promote forest investments for the first time. It helped to set the groundwork and the legal framework to implement and operate the Grain for Green Program.

sheds, reduction of desertification, and restoration of ecosystems). Rapid exploitation, little concern for regeneration, and ineffective afforestation after 1962 in forestry finally resulted in devastating floods of the Yangtze River in the summer of 1998 (Robbins and Harrell, 2014). Environmental and ecological problems of the late 1990s forced the government to change course and institute a very extensive reforestation program, the Grain for Green (or Sloping Land Conversion) program.

The GfG Program is one of the world's largest PES programs, enrolling 40 million hectares at a cost of $100 billion funded entirely by the central government (Wang et al., 2007; Cao et al., 2011). The GfG Program generously compensates farmers for enrolling farmland conversion by offering them a combination of cash, grain, and free saplings. Payments vary regionally (see Figure 1). In the middle and upper reaches of the Yellow River and its northern region, the compensation package has a monetized value of RMB 3,150/ha (equivalent to $380.51/ha in 1999) for the first year, and RMB 2,400/ha (equivalent to $289.91/ha in 1999) from the second year on. The corresponding values in the middle and upper reaches of the Yangtze River and its southern region are RMB 4,200/ha ($507.35/ha) and RMB 3,450/ha ($416.75/ha)(Uchida et al., 2005).[3] Subsidies are paid over 8, 5, or 2 years for cropland conversion to timber-producing forest, orchards, or pasture, respectively. Timber-producing forest serves mainly an ecological function initially, as farmers cannot harvest forest products from it during the period in which subsidies are paid. In contrast, farmers are allowed to harvest non-timber products from orchards (Grosjean and Kontoleon, 2009). Timber-producing forest and orchards increased substantially when the GfG Program started (Figure 2).[4]

The GfG Program is primarily designed to reduce the amount of hillside and degraded farmland (as well as suitable unused land) for ecological benefits (Xu et al., 2006). Afforestation on these lands helps to reduce soil erosion and protect watersheds, as well as restoring

[3] Suitable unused land conversion has less compensation than farmland conversion, it includes free seed and seedling compensation and the cash subsidy of RMB 50/ha/year (the Regulations, Article 36).

[4] The apparent lag in the increase of orchards is likely be due to the regulations requiring newly afforested area to consist of at least 80% of timber-producing forests and at most 20% of orchards.

ecosystem and preventing desertification.[5] Program guidelines stipulate that basic farmland should be preserved given China's concern for self-sufficiency in food production.[6]

The regulations governing the GfG Program, the Regulations on Conversion of Farmland to Forests (hereinafter the Regulations), prohibit unauthorized tree harvesting or damage to ecological functions even after expiration of subsidies (the Regulations, Article 50).[7] The Regulations also emphasize the preservation of farmland that has relatively good productive conditions or has no potential cause of soil erosion, especially basic farmland (the Regulations, Article 4 and 16).[8] Thus, the program targets hillside farmland and unused land affected by soil and water erosion or land with low and unstable grain yield. The slope of the land is the top criterion for farmland enrollment because hillside land is highly vulnerable to erosion and causes nonpoint source pollution (Xu et al. 2004; Feng et al. 2005; Long et al. 2006; Ouyang et al. 2007; the Regulations, Article 15).

Although the policy has emphasized the importance of land targeting, only a few studies have examined this issue. Early descriptive studies suggest the presence of mis-targeting problems, with high-quality, low-sloping land enrolled under the program, while high-sloping low-quality land remained in cultivation in some counties (Xu et al., 2004; Uchida et al., 2005). Whether this is a prevailing phenomenon nationwide and the possible causes of mis-targeting remain unknown. In addition to the highly erodible farmland set-asides, the program aims to develop the rural economy and alleviate poverty, as well as encouraging gradual off-farm migration (Xu et al., 2004). However, these diverse goals may conflict with

[5] The program was initiated to return farmland with slopes of 25 degrees or more to forests in the upper Yangtze River and Yellow River Basins as a pilot in Sichuan, Shaanxi, and Gansu provinces (Ye et al., 2003). It expanded nationwide beginning in 2000 to cover almost all of China. After a rapid 3-year roll-out, 1,897 counties from 25 provinces, autonomous regions, and municipalities have progressively enrolled into the program in 2002 (Deng et al., 2012).

[6] Basic farmland is a type of land under the protection of the Land Administration Law in China. It is relatively flat and has irrigation and drainage facilities.

[7] Reclamation and damaging surface vegetation are considered as criminal activities prohibited by the Forest Law, the Grassland Law, and the Law of Water and Soil Conservation (the Regulations, Article 62).

[8] Basic farmland includes farmland with good irrigation and water conservation facilities even the current yield is low. Basic farmland is forbidden for tree planting or fish nurturing, but only limited to agricultural uses (the Land Administration Law, Article 34 and 36). This type of land should not be converted under the GfG Program.

each other at some levels (Gauvin et al., 2009; Robbins and Harrell, 2014). Most studies of the GfG Program have focused mainly on objectives relating to rural households' livelihoods, including grain production (Feng et al., 2005; Xu et al., 2006), rural household incomes, and off-farm opportunities (Uchida et al., 2009; Yao et al., 2009; Xu et al., 2010; Li et al., 2011).

While the central government sets policy, it relies on local governments to implement those policies and monitor compliance. The administrative structure of the GfG is thus a highly decentralized program in practice. However, the incentives of local officials have not always aligned with those of the central government (Tao et al., 2004; Xu et al., 2004). The county governments are responsible for coordinating its implementation, and the county-level authorities are able to adapt and adjust the program to the local needs and conditions (Delang and Yuan, 2015). Local officials have had little incentive to ensure that only highly erodible farmland is converted to forest since local officials may have expected to be rewarded on the basis of total conversion. Consequently, if reforestation subsidies made it attractive, farmers might well convert productive, non-erosion-prone farmland to forests, regardless of formal restrictions on farmland conversion (Uchida et al., 2005; Long et al., 2006; Xu et al., 2010). Although excess farmland conversion is usually caused by the increased policy enforcement in developed countries (Pattanayak et al., 2010), this type of unintended land use consequence happens in China due to relatively weak governance. This phenomenon is likely to happen in developing countries with relatively weak or decentralized governmental systems.

3 Conceptual Model

This section contains a theoretical model deriving the conditions under which it is optimal for local officials to use the GfG Program to subsidize afforestation of (potential-) high productivity farmland on level ground, contrary to the intended purpose of the program. Converting highly erodible farmland to forests has positive externalities with ecological benefits that affect the whole country, such as preventing soil erosion and reducing sedimentation, flooding, and nonpoint source pollution. There is little or no excess of social benefit over private benefit from afforestation on level farmland. Although the stated policy goal is to subsidize afforestation only on highly erodible hillside land, early survey results in some counties suggest that the program unintentionally paid for converting level farmland as well (Tao et al., 2004; Uchida et al., 2005; Xu et al., 2010). A potential cause is weak monitoring by the central government, which delegates both monitoring and vegetation management to officials at the county level (the Regulations, Article 31). Because local governments usually implement the GfG without transparency in the details of implementation, the most appropriate fields to enroll may not be selected carefully (Uchida et al., 2007; Delang and Yuan, 2015). Under some conditions, county officials may have incentives to expand afforestation beyond hillside and unused land, and may thus be reluctant to enforce the "slope rule".

The following conceptual model of farmland conversion is developed to explore conditions when the unintended conversion is likely to happen. It assumes that the central government has difficulty enforcing the farmland preservation requirement because it relies on local officials to both implement the program and monitor compliance. The land allocation process under the program can be considered as decision-making actions performed by the same local officials, because of the rural land tenure insecurity and ultimate land control by local leaders (Jacoby et al., 2002; Cai, 2003; Deininger and Jin, 2003). In the GfG Program, in particular, local officials have been shown to exert a great deal of influence over land allocation (Xu et al., 2004; Uchida et al., 2005).

To simplify the exposition, possible land uses are restricted to farmland and forest land (F). With goals to protect basic farmland but also to convert hillside cropland, farmland is separated into two types: high productivity farmland on level ground (A_l) and highly erodible farmland on hillsides (A_e), only the latter of which is targeted by the program. $F > 0$, $A_l > 0$, and $A_e > 0$ denote the initial endowments. Let a_l and a_e denote the levels of level and highly erodible farmland converted to forest, respectively, in a local area. Positive (negative) a_l or

a_e means an increase in forest (farmland) cover.[9] To account for the differential quality of land, define the relative forestry productivity with converted land from highly erodible farmland to the one from level farmland as $0 < \varepsilon \leq 1$.[10] Let $B(a_l, a_e) = B(F + a_l + \varepsilon a_e)$ and $\pi_j(a_j) = \pi_j(A_j - a_j)$ represent the instantaneous benefits or revenues from forestry and agricultural sectors, with $j = \{l, e\}$ representing revenue from level and highly erodible farmland, respectively. They are functions of land alone under the assumption that labor and capital used in production are not constrained, i.e., they adjust instantaneously with the land.

The costs of conversion include both labor costs and seedling purchases. Because the seeds are produced locally and redistributed to adjacent areas in this program (the Regulations, Article 26), transportation costs and profit seeking from seedling purchases can be ignored. Let $C_l(a_l)$ and $C_e(a_e)$ represent the total cost of converting level and erodible farmland, respectively. Assume diminishing marginal returns of the benefit and revenue functions, $B'(\cdot)$, $\pi_j'(\cdot) > 0$ and $B''(\cdot)$, $\pi_j''(\cdot) \leq 0$, and convex cost functions $C_j'(a_j) > 0$, $C_j''(a_j) \geq 0$ when $a_j > 0$ and $C_j'(a_j) < 0$, $C_j''(a_j) \geq 0$ when $a_j < 0$. The costs of converting farmland to forest and forest to farmland are assumed to be different. I assume tree logging and land reclamation requires higher effort than reforestation on farmland: $-C_j'(\hat{a}_j) > C_j'(\tilde{a}_j)$ when $\hat{a}_j < 0 < \tilde{a}_j$ and $\hat{a}_j, \tilde{a}_j \in a_j$. The cost functions are kinked at the origin and $C_j'(0)$ is undefined. The subsidy for converting a unit of farmland of either type is fixed. Let S be the total monetized subsidy payment per unit of farmland conversion, and $S \cdot [\max(a_l, 0) + \max(a_e, 0)]$ be the total compensation the local area received because of the unintended payment to level farmland. Assume S is converted to the present value at the first year's implementation.

The local official chooses the area of level and highly erodible farmland to enroll in the

[9] I assume $a_l < A_l$ and $a_e < A_e$ in order to concentrate on the interesting case where an unintended leakage might occur. The assumption reduces only two corner solutions that are less likely to happen and are not the focus of the paper.

[10] For simplicity, assume the relative forestry productivity of converted land from level farmland to existing forest land as 1. Adding another quality adjust factor will yield similar results but complicate the model.

GfG Program to maximize net benefits of land:

$$\max W(a_l, a_e) = V(a_l, a_e) + S \cdot [\max(a_l, 0) + \max(a_e, 0)]$$

s.t. $a_l < A_l$ and $a_e < A_s$

where $V(a_l, a_e) = B(F + a_l + \varepsilon a_e) + \pi_l(A_l - a_l) + \pi_e(A_e - a_e) - C_l(a_l) - C_e(a_e)$

Note that the individual rationality condition should also be satisfied: prior to the subsidy (when $S = 0$), no additional conversion is needed because land must have been distributed across the three types of land in an optimal way, i.e., $(0, 0)$ solves $\max V(a_l, a_e)$. Because $C_j(x)$ is kinked at the origin, so is $V(a_l, a_e)$, and the conditions $V_j^+(0, 0) \leq 0$ and $V_j^-(0, 0) > 0$ are assumed to be satisfied to guarantee this optimum.[11] The superscripts + and − denote right and left partial derivatives. The subscript j under V or W represents partial derivatives with respect to a_j.

An implicit requirement to the local condition is also needed: $V_l^+(0, 0) < V_e^+(0, 0)(\leq 0)$, in order to guarantee that certain subsidy level is able to induce only afforestation of the highly erodible farmland in that region. The condition means that even if forest output on the level farmland would be weakly more valuable, afforesting on one unit of level farmland results in a higher loss than afforesting on one unit of highly erodible farmland.

Conditions of Unintended Level Farmland Conversion

The primary interest here is to find out when converting level farmland is more likely to occur, which is equivalent to deriving the conditions under which farmers convert only highly erodible farmland. All cases violating these conditions may lead to unintended leakage. Because $W_j^+(0, 0) = S + V_j^+(0, 0) > 0$ implies $a_j > 0$, $S + V_l^+(0, 0) \leq 0 < S + V_e^+(0, 0)$ is required in order to follow the Regulations without conversion of level farmland. This is equivalent to the following two conditions that the subsidy level must satisfy:

$$S + B'(F) - \pi_l'(A_l) - C_l'(0^+) \leq 0 \tag{1}$$

$$S + \varepsilon B'(F) - \pi_e'(A_e) - C_e'(0^+) > 0 \tag{2}$$

[11] The conditions can be interpreted as converting one additional unit of farmland(forest) to forest(farmland) costs more effort than the received land values.

Violating these conditions may lead to not only the cases of positive conversion in both types of farmland (when both (1) and (2) are positive) or no participation in the program (when both (1) and (2) are nonpositive), but also the possibility of afforestation only on level farmland (when (1) is positive and (2) is nonpositive). The condition is more likely to be violated when one or more situations described in the following two paragraphs happen.

Condition (1) is more likely to be violated in areas that have (a) higher marginal value of forest, (b) lower marginal value of level farmland, (c) relatively lower marginal cost of converting level farmland, (d) lower stock of forest, or (e) higher stock of level farmland. The first three conditions are most likely to be found in western China, where crop profitability is low relative to forest profitability, and where level farmland conversion is relatively easier with low rural population density. Western China also has a relatively low stock of forested land due in part to deforestation during the Great Leap Forward period. Some conditions are also satisfied in eastern China, where has a high stock of level farmland, and where forest profitability is relatively high.[12]

Condition (2) is more likely to be violated in areas that have (a) lower marginal value of forest, (b) higher marginal value of highly erodible farmland, (c) relatively lower marginal cost to convert highly erodible farmland, (d) higher stock of forest, (e) lower stock of highly erodible farmland, or (f) subsidy levels are relatively low to local conditions. These conditions are most likely to be found in southern China, which has the low stock of highly erodible farmland, low forestry productivity, and an average output of farmland 1.5 times as much as that in northern China. Average local governmental revenue is also higher than northern China. These conditions give farmers and local authorities in southern China less incentive to participate in the program.

Factors Affecting the Amount of Level Farmland Conversion

This subsection explores the conditions under which excess conversion of level farmland is

[12]Figure 3 shows the regions of China.

likely to be more extensive. In the case of converting both types of farmland, there are a pair of interior solutions for the the maximization problem, $a_l^* > 0$ and $a_e^* > 0$, with detailed comparative statics included in Appendix I.

Note first that a higher unit subsidy increases the optimal converted amount of highly erodible farmland. However, the direction of the subsidy's impact on the conversion of level farmland is ambiguous and depends on the size of the relative forestry productivity of converted farmland, ε. When ε is close to 1, i.e., when forest land converted from both types of farmland have similar forestry productivities, a higher unit subsidy increases the optimal converted amount of level farmland. While when ε is close to 1/2, whether high subsidy will include more conversion of level farmland is ambiguous.[13] It is thus possible that an increased unit subsidy could discourage the conversion of level farmland. For instance, in arid or semi-arid western China, forest land converted from highly erodible farmland without irrigation facilities is likely to have a lower forestry productivity than the one converted from level farmland. A higher unit subsidy in southwestern China could thus decrease the optimal converted amount of level farmland instead.

It is also straightforward to show:

1. A smaller amount of forested land or a higher value of forest production leads to a higher optimal converted amount of both types of farmland.
2. A larger amount of level (highly erodible) farmland, or a lower value of its farmland value, leads to a higher optimal converted amount of level (highly erodible) farmland, and lower optimal converted amount of highly erodible (level) farmland.
3. Larger conversion costs of highly erodible farmland relative to the one of level farmland leads to a larger (smaller) amount of level (highly erodible) farmland conversion.

These results are intuitive and suggest different land use impacts driven by local conditions. Farmers in western China may be more likely to convert both types of farmland due to their

[13]The other possibility is when ε converges to 0, though it is less interesting and less likely to happen. Because this suggests highly erodible farmland converting to forest with almost no forestry productivity as if it was completely abandoned, which would backfire the design of the GfG Program, the one intended to convert only highly erodible farmland (and suitable unused land) to forest.

low forest endowment, and to convert more level farmland when converting highly erodible land on hillside is relatively costly. Farmers in eastern China own high stock of farmland on level ground and low stock of forest, both of which could induce them to convert more level farmland. Participation and conversion of farmland to forest are likely to be low in southern China, where agricultural profitability is high both absolutely and relatively to returns to forestry.

4 Data

To test the hypotheses derived in the preceding section, I create a unique panel of land use data from the Ministry of Land and Resources (MLR) of China and socioeconomic data from statistical yearbooks. The land transition data comes from confidential records maintained by MLR from 1996 to 2003 at the county level (the data of land stock for each category is from 1996 to 2004).[14] The data includes endowments and transitions for all types of land that measured to the nearest 0.1 *mu* (1 *mu* is equivalent to 1/15 hectare), and converted to hectares. There are several major advantages of the data: (1) the data documents the uses land came from and went to for 8 major land categories and 47 minor categories; (2) the data allow me to address afforestation of unused land, which has largely been ignored in the previous literature; and (3) with the nationwide data, I am able to for the first time evaluate the land use and land cover impacts of the GfG Program in the whole country and examine the regional heterogeneity.

Level and highly erodible farmland are differentiated according to two criteria, the land gradient and the presence of irrigation facilities. These criteria are used to define basic farmland as well (the Land Administration Law, Article 34). Irrigated paddy and irrigated cropland are characterized as level farmland, and rain-fed paddy and dry land as highly erodible farmland. Both irrigated paddy and irrigated cropland have flat topography and

[14] Since 1996, land use reports are all based on this 1996 China's Land Survey, the one has widely accepted reliability and provides the most systematic and comprehensive quantification measurement of China's land (Lin and Ho, 2003; Feng et al., 2005).

relatively high-level productivity. These types of arable land fit the classification of basic farmland, and have sufficient water and irrigation/drainage facilities.[15] In general, they are not the target of the GfG Program. Rain-fed paddy and dry land, on the other hand, both are located in the middle and upper parts of mountains and hills, suggesting the land is hilly. Hilly land is more prone to soil erosion and has less organic matter content (and is thus less fertile; see Feng et al., 2005). Grain yield from these types of land depends on natural precipitation and is thus variable. These two types of land fit the target of the GfG Program described in the Regulations.

County-level socioeconomic data for the corresponding time period is collected from the statistical yearbooks published from 1997 to 2004. The data includes GDP by sector (primary, secondary, and tertiary), the value of grain and forestry output, rural labor population, and local government's revenue and expenditure, all measured at the county level.[16] All the monetary variables in Chinese RMB are normalized to real 2005 terms, and converted to US dollars using the 2005 average annual exchange rate. GDP deflators for each sector are used to deflate the local GDP from respective sectors. Both GDP deflators and exchange rates are provided by the Federal Reserve Bank of St. Louis.

In addition to the land use and socioeconomic variables, another important term is the indicator for the GfG Program, which is 1 if the policy is in effect and 0 otherwise. The GfG Program was phased in gradually. It was implemented in Gansu, Sichuan, and Shaanxi provinces in 1999; Yunnan, Guizhou, Chongqing, Hubei, Qinghai, Ningxia, Inner Mongolia, Shanxi, Henan, and Xinjiang in 2000; Hebei, Heilongjiang, Jilin, Liaoning, Hunan, Guangxi, and Jiangxi in 2001; and Beijing, Tianjin, Anhui, Henan, and Tibet in 2002 (The GfG Office of National Forestry Administration, 2000; China Forestry Statistical Yearbook 2001, 2002;

[15]From the definition of basic farmland, even low-yield fields can be classified as basic farmland as long as they are equipped with good irrigation practices and water conservation facilities (the Land Administration Law, Article 34).

[16]Two types of statistical yearbooks are used: annual Provincial Statistical Yearbooks and Chinese Counties (Cities) Socioeconomic Statistic Yearbooks. The first one contains data at the provincial and prefectural level, with partial county-level data provided, and the second one provides more observations for certain variables.

Deng et al., 2012). The phase-in process was complete in 2002, and the GfG Program became a nationwide program covering 25 out of 31 provinces, autonomous regions, and provincial level municipalities.[17] Table 1 includes the descriptive statistics of the data I use.

5 Empirical Model

I use the panel of land transition data to test the hypotheses derived in the theoretical section. I examine the subset of conversions between forested land, level farmland, and highly erodible farmland. The theoretical analysis indicates that the amount of land converted from use j to use k in county i at time t, a_{jkit}, is a function of the GfG subsidy (specifically, whether the GfG Program was in effect), the amount of land of each type at the beginning of the period $\boldsymbol{A_{it}}$, and other factors influencing land conversion, $\boldsymbol{X_{it}}$:

$$a_{jkit} = \beta_{0i}^{jk} GfG_{it} + \boldsymbol{\beta_A^{jk} A_{it}} + \boldsymbol{\beta_X^{jk} X_{it}} + e_i + e_t + e_{it} \tag{3}$$

Other factors, $\boldsymbol{X_{it}}$, include crop profitability and forestry profitability (proxied by the value of farmland and forested land in county i at time t), the relative conversion cost (proxied by the rural labor density in county i at time t), and local government's financial status (annual revenue and expenditure). The value of land is measured by GDP or output divided by the corresponding land area. Specifically, the average values of farmland, timber-producing forest, orchards, and urban land are calculated or proxied as grain output per unit of farmland, output of forestry per timber-producing forest, output of fruits per unit of orchard, and secondary and tertiary industrial GDP per unit of urban land, respectively.[18]

The theoretical model suggests that unintended level farmland conversion is more likely to happen in certain regions due to regional heterogeneity. I estimate the following equation

[17] Farmland in southeastern China has low degradation risk and high yield, and has equipped with sufficient water and irrigation facilities. However, its farmland size has been shrinking (National Bureau of Statistics of China). Thus, provinces in southeastern China do not participate in the program.

[18] The value of urban land is added as a robustness check. Rapid urbanization has been shown to lead to the conversion of farmland into urban uses (Lichtenberg and Ding, 2009), road expansion may have impacts on forests (Uchida et al., 2009), so incentives for urban expansion may indirect influence on farmland transitions to other uses. The estimated results are robust with this variable, and only the results with urban value included are reported.

by breaking down Equation (3):

$$a_{jkit} = \beta_{0i}^{jk}(GfG_{it} \cdot region_i) + \boldsymbol{\beta_A^{jk}} \boldsymbol{A_{it}} + \boldsymbol{\beta_X^{jk}} \boldsymbol{X_{it}} + e_i + e_t + e_{it} \quad (4)$$

where $region_i = south$ or $north$ to distinguish the effect of subsidies and production conditions.[19]

The theoretical model suggests there may be a critical value of farmland at which unintended conversion leakage occurs: lower (higher) value of level (highly erodible) is more likely to be converted (maintained). I observe only average farmland value in each county. I create two variables, $farmland\_value_{lit}$ and $farmland\_value_{eit}$, using the farmland shares in each county and the average farmland yield ratio (Hong et al., 2014) to represent the average level farmland value and the average highly erodible farmland value, respectively. In order to test this hypothesis and estimate the critical value for each type of farmland in different regions, two other variables, $GfG_{it} \cdot farmland\_value_{jit}$ (or $GfG_{it} \cdot region_i \cdot farmland\_value_{jit}$ in Equation (4), where $j = l$ or e), are added to evaluate the impacts of cropland productivity:

$$a_{jkit} = \beta_{0i}^{jk}(GfG_{it} + \beta_{1i}^{jk}(GfG_{it} \cdot farmland\_value_{jit}) + \boldsymbol{\beta_A^{jk}} \boldsymbol{A_{it}} + \boldsymbol{\beta_X^{jk}} \boldsymbol{X_{it}} + e_i + e_t + e_{it} \quad (5)$$

Equations (3) to (5) use county and time fixed effects model to control for unobserved heterogeneity. Given the context of a small time period and large observations for each year, the model uses *cluster-robust* standard errors to cope with possible serial correlation and heteroskedasticity (Wooldridge, 2011). The effects of the program are estimated by β_{0i}^{jk}s (and β_1^{jk}s in Equation (5)) from the land use outcomes of the two groups: the observations affected by the GfG Program, and the non-participated observations, after controlling for observed influences and unobserved factors in each county in a given year. The expected signs for β_0^{jk}s are positively significant for all land transitions. The expected signs for β_1^{jk}s are negatively significant when j is level farmland or highly erodible farmland.

To adjust for the level of land endowments and explore the relative sizes of unintended conversion leakage in different regions, I estimate another model with shares $a_{jkit}/A_{ji,t-1}$ as the dependent variable in Equation (3) and (5). The coefficients β_0^{jk} and β_1^{jk} in the share

[19] I also estimate a model to identify the program's regional impacts by further breaking down the equation by allowing $region_i = southwest$, $southcentral$, $northwest$, $northcentral$, and $northeast$.

model show the effects of the GfG Program on a certain type of land relative to its total endowment. The expected signs for then are the same as in Equation (3) and (5).

The main focus of the empirical analysis is to investigate whether the GfG Program causes unintended conversion of level farmland to forest and, additionally, the extent to which this unintended leakage depends on the value of farmland. To put the unintended leakage in context, I examine six types of transitions from three sources (level farmland, highly erodible farmland, and suitable unused land) to two end uses (timber-producing forest and orchards). Although two types of afforestation are subsidized, only significant conversion to timber-producing forest is expected due to the conversion restriction on orchards (see Section 2). Because the theoretical analysis suggests that the effects of the program are likely to differ across regions, descriptive statistics of the data used in the regression for regions are given separately in Table 1.

Table 2 and 3 show the estimated coefficients of the GfG indicator for the pooled and regional disaggregated models. Table 2 provides the land transitions from farmland or suitable unused land to timber-producing forest and orchards under the GfG Program from 1996 to 2003. Table 3 provides the corresponding estimates in the share model. Because county sizes likely differ substantially, I conduct two robustness checks: (1) use county size as a weight in weighted least squares and (2) add county size as a control variable. Since the results are almost identical, I report only the results from the second. Changing the identification of $farmland\_value$ from output grain/ha to GDP of primary industry/ha, value added of primary industry/ha, output value of farm/ha, and output of grain/ha from another source of data also provides virtually identical results and thus are not reported. Dropping the top or bottom 5% and 10% of the transitional observations also yields estimated coefficients of the same magnitude, suggesting the estimated coefficients are not influenced by outliers. The results of the robustness checks are included in Appendix II.

To examine the validity of the parallel trend assumption, I conduct two tests: (1) estimating differences in time trends in treated versus un-treated provinces in the pre-treatment period and (2) a placebo test re-estimating the DID model over the pre-treatment period. I first check the differences in the pre-treatment trends of the treatment and comparison groups separately for each cohort of provinces that implemented the GfG Program in a given year. As Figures 4 and 5 show, there are no discernible differences in pre-treatment trends in average conversion to timber-producing forests from level farmland and highly erodible farmland, respectively. I also perform a set of placebo tests for each implementation-year cohort. I estimate the farmland transition model under the assumption that the program was implemented in 1997, 1998, 1999, and so on up to a year before the end of the sample period. The estimated coefficients of the GfG indicator for the level farmland and highly erodible farmland conversion showed in Figures 6 and 7 are not significantly different from zero. Comparisons and placebo tests of other types of conversion are very similar and not reported.

6 Estimation Results and Implications

Tables 2 and 3 report estimated coefficients of the absolute area and share models, respectively. In general, the estimated coefficients have signs consistent with expectations. The first panel of each table reports the coefficient of the GfG Program indicator in Equation (3). The second and the third panels show the coefficients of the GfG indicator interacted with regional dummies. All models include a complete set of covariates along with county and year fixed effects. Because the Regulations require that newly afforested area be composed of at least 20% orchards, the following subsections focus mainly on timber-producing forest.

6.1 Effects of the GfG Program on Highly Erodible Farmland

The stated goal of the GfG Program is to convert highly erodible farmland to timber-producing forest in order to prevent soil degradation and water erosion. The estimated coefficients of the GfG indicator suggest that the program was quite successful in meeting that goal, with an estimated 6% of highly erodible farmland converted to timber-producing forest in the four years from initial program implementation to the end of the study period. At the average timber-producing forest value in each region, the estimates indicate that the cumulative effect of the GfG Program over the whole study period (1999-2003) was afforesting timber-producing forest with a value of nearly $ 21.84 million.[20]

Regional analysis suggests significant geographical heterogeneity in the effects of the program. Consistent with the theoretical analysis in Section 3, highly erodible farmland conversion was higher in northern China, which has large a endowment of highly erodible farmland, a low endowment of forested land, and relatively low farmland productivity. Highly erodible farmland conversion in northern China is significantly greater than it is in southern China ($F(1, 6008) = 54.18$ and $p - value = 0.000$).

The regionally disaggregated coefficients indicate that the program was most successful in northwestern, northeastern, and south central China. This finding is consistent with the prediction in Section 3, because these regions have larger endowments of highly erodible farmland and higher forestry value. Northern China also has a large stock of highly erodible farmland and relatively low farmland productivity. With the highest endowment of highly erodible farmland and forestry productivity, northeastern China has the highest conversion, which is almost twice as much as the second highest (in northwestern China) with a statistically significant difference ($F(1, 6004) = 10.52$, and $p - value = 0.001$). These two regions would have converted 10.0% and 6.3% of highly erodible farmland to forest after four years of implementation, respectively. In contrast, central China is less likely to participate in the program due to a higher farmland productivity, a lower hillside farmland stock, and a lower return in forestry. South central China, although its size of conversion is relatively similar to that of north central China ($F(1, 6004) = 0.01$ and $p - value = 0.9144$), has a relatively low endowment of highly erodible farmland. Thus, its conversion share is sizable, amounting to

[20] To calculate this, I multiply the average value of forest in each subregion (northwestern, north central, northeastern, southwestern, and south central China) with the number of counties that participated in the program in each subregion and year, then add up all the regions.

12.5% of highly erodible farmland conversion after four years of implementation.

The GfG Program was designed to incentivize conversion of farmland to timber-producing forest rather than orchards. Consistent with that program design, the GfG Program had a smaller effect on conversion of farmland to orchards. Two features of the program's design are likely responsible: (1) the low monetary value of subsidy packages for orchard and (2) the requirement that orchards account for no more than 20% of total afforestation, which the central government was able to realize by rationing free seedlings of orchard trees. Only in northeastern China, where orchards are relatively profitable, was a substantial amount of erodible farmland converted to orchards.

6.2 Unintended Land Use Effects of the GfG Program

The GfG Program targeted highly erodible hillside land but specifically exempted productive farmland with little risk of soil erosion. Unintended conversion of productive, low erosion risk land to forest yields little environmental benefit, but is costly in terms of risks to food security as well as excess spending on subsidies. Table 2 suggests this type of unintended conversion was substantial, amounting to nearly one-fifth of the total amount of cropland converted to timber-producing forest.

Consistent with the theoretical analysis in Section 3, the estimated coefficients in Table 2 indicate that unintended level farmland conversion was greatest in northern China, where this type of unintended leakage was as nearly three times more than southern China.[21] Cumulatively, this form of leakage caused a 2.5% loss in total stock of level farmland during the study period in northern China.

The theoretical model also predicts the unintended conversion could be considerable in both eastern and western China,[22] because the former has relatively high returns in forestry and high stock of level farmland and the latter has relatively low stock in forestry, low returns of level farmland, and relatively low-cost conversion of level farmland. Western China has

[21] The difference is statistically significant with $F(1, 5560) = 18.66$ and $p - value = 0.000$.

[22] But not central China; see Figure 3 for the regional reference

a low stock of productive level farmland, so that a 0.2% - 0.45% annual rate loss of level farmland per county due to the program represents a sizable relative loss of productive capacity. Unintended conversion of high quality farmland is also substantial in the southern part of central China, where forested area is relatively small but value of forest production is relatively high. In this region, unintended conversion amounted to nearly one-fourth of the total amount of cropland converted to timber-producing forest.

6.3 Impacts of Farmland Productivity and Poverty Alleviation

PES programs in many countries have the dual goals of environmental protection and poverty alleviation. In regions where crop productivity is low relative to reforestation subsidies, emphasis on poverty alleviation can result in preferential enrollment of land at low degradation risk (Landell-Mills et al., 2002; Lipper et al., 2009). My theoretical analysis of the Chinese situation indicates that unintended conversion is more likely to occur in areas where the value of farmland is relatively low. I investigate this possibility by calculating breakeven levels of cropland productivity at which conversion to timber-producing forest becomes desirable. These estimated breakeven levels, shown in Table 4, are calculated using the coefficients of models with interaction terms shown in Table 5. The breakeven levels imply that in some parts of China, high-quality, low degradation risk farmland was enrolled under the program while low-quality, high degradation risk farmland remained in production, consistent with the findings of earlier descriptive studies (Xu et al., 2004).

At the national level, the breakeven grain yield for level farmland is 1.25 times higher than corresponding values for highly erodible farmland. The difference in breakeven yield implies that some level farmland was converted to forest, while some lower yielding, highly erodible farmland remained in crop production. In northern China specifically, where unintended leakage is high, the difference in breakeven yield indicates that highly erodible farmland with nearly 36.4% lower yields remained in production while some level farmland was converted to forest. The breakeven yield differential discrepancy was the greatest in north central China, reaching 49.0%.

One possible explanation for the difference in breakeven yields between level farmland and highly erodible farmland is the relative cost of land conversion. As indicated by the theoretical model, higher amounts of this unintended leakage can occur in areas where it is considerably more costly to convert highly erodible farmland to forest than it is to convert level farmland. In relatively poor areas, such as the western and central parts of northern China, land conversion depends mainly on rural labor. Rural labor density is low in northern China, making labor more scarce and costly. Since converting highly erodible farmland to forest requires more labor than does converting level farmland, the relative conversion cost differential tends to be high, making it attractive to convert high quality farmland while leaving highly erodible farmland in production.

6.4 Policy Implications

At the national level, the Ministry of Forestry (MOF)[23] is responsible for afforestation and forest management. The MOF has its own hierarchical structure at provincial, prefecture, and county levels. Forestry departments at the county level are charged with both implementing and monitoring GfG and other programs. However, environmental administration at the local level is generally controlled by local leaders (OECD., 2005; Wu, 2005). While lower level forestry authorities report to higher level ones, funding and supervisory functions are provided by provincial or lower level administration. Essentially, the GfG Program gives local authorities incentives to allow highly productivity level farmland to be converted to forest, while simultaneously giving these same officials the authority to ensure compliance with restrictions on farmland conversion.

If lack of independent compliance monitoring is in fact the cause of unintended land displacement, then it could be reduced or even eliminated by the central government establishing its own independent monitoring system as a check on local authorities' behavior. As

[23]Or called State Forestry Administration (SFA) in some literature

a rough estimate of the potential avoided loss from establishing an independent compliance monitoring system, I calculate the sum of (1) subsidies paid to cropland subject to the unintended conversion and (2) the value of lost grain production net of the increased forest production value. Because the land displacement is substantial in certain regions of China, amounting to one-fifth of total forest conversion annually, excess subsidy payments for this unintended land conversion amount to $581.3 million.[24]

Valued at the central government's average grain price (1.4 yuan per kilogram of grain), the potential savings in grain production is roughly $107.9 million.[25] The estimated corresponding value of forest products is $2.92 million. Thus, potential avoidable net losses are around $677.06 million from 1996 to 2003, or $140,498 per participating county per year. In northwestern and northeastern regions of China, which have relatively sizable unintended leakage, the total avoidable losses reached $ 257,726 per county per year, suggesting the compliance monitoring system could double the budget if it focuses on these two regions alone.

Whether an independent central government compliance monitoring system would be economical depends on the cost and effectiveness of that system. Nevertheless, the preceding calculations suggest that independent compliance monitoring could be well worthwhile for the central government.

[24] I calculate the average payment to level farmland conversion per county per year by multiplying the regionally differentiated subsidy level to the estimated annual leakage. Multiplying the average payment by the number of counties that receive the subsidy in each region (northwestern, north central, northeastern, southwestern, and south central China) and each year yields the regional potential avoided payments. Then I add up all the regions to receive the total potential reduction. Note that the number of participated counties varies region-to-region and year-to-year. The total number of county-year observations with the GfG Program in-effect is 4819 from 1996 to 2003.

[25] I first find the estimated annual loss of grain in value by multiplying the grain price to the average yield in each county per year. Multiplying the average value of yield lost by the estimated annual leakage and the number of counties that receiving the subsidy in each region and year yields the regional loss in grain production. Then I add up all the regions to receive the potential savings in grain production.

7 Conclusion

Starting in 1999, the Chinese government implemented an extremely ambitious afforestation program, Grain-for-Green (GfG), with the aim of preventing soil erosion by converting highly erodible and degraded farmland to forests and pasture. GfG is widely considered a great success. China's concern for self-sufficiency in food production led to restricted conversion of high quality farmland on level ground. Authority for compliance is delegated to local officials whose incentives may not align fully with the central government's. This paper studies the potential unintended land use effect of converting productive farmland for conservation uses, which undermines the country's goal of protecting productive farmland.

Studies on unintended land use effects of the PES programs have mainly focused on slippage or leakage, i.e., additional deforestation due to PES-payment-induced farmland expansion. This phenomenon usually occurs in countries or regions with abundant arable farmland, where the main problem is unintended deforestation offsets. The opposite of that effect is considered as positive spillovers to mitigate the slippage. However, in countries such as China, where arable land is scarce relative to population, this situation creates legitimate concerns about food security. Therefore, unintended conversion of productive farmland to conservation uses poses a significant risk in China and other countries with similar land concerns. The type of land displacement explored in this paper, which has not been recognized in the literature to date, can be a crucial problem in countries with limited arable land and an understandable interest in food self-sufficiency goals.

This study uses a simple theoretical model to analyze where this form of leakage is likely to occur. It then estimates the magnitude of excess conversion of productive farmland in China using a unique land transition-use dataset merged with the official social-economic data from 1996 to 2003. The paper finds substantial leakage in western and coastal China, especially in the northern portions (where the lower tier of subsidy was paid), consistent with predictions derived from the theoretical model. Also as predicted, this leakage is more prevalent on lower-value land. The results of the empirical analyses suggest that it might be worthwhile for the central government to establish a compliance monitoring system to avoid losses in both crop production and undesirable subsidy payments.

In general, studies of land use effects of PES programs need to consider both traditional and "reverse" slippage effects. For China specifically, this paper provides elements of a more nuanced evaluation of China's GfG Program. It also points out some weaknesses in China's governance system, which delegates a great deal of authority to local officials with potentially insufficient checks on the part of the central government. Consideration of how the central government might implement compliance monitoring is beyond the scope of this paper, however, and is left for future research.

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Table 1: Descriptive Statistics of Data Used in Analysis in Eastern, Central, and Western China from 1996 to 2003

	Subregions by Geography						Subregions by Subsidy Level			
	Eastern		Central		Western		Northern		Southern	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Transition from high quality farmland to forest (ha)	1.473	38.867	4.301	50.275	1.908	122.519	1.299	114.377	3.399	40.756
and percentage transition (from year t to t+1)	0.002	0.043	0.002	0.030	0.000	0.018	0.001	0.037	0.002	0.024
Transition from low quality farmland to forest (ha)	73.156	531.318	54.023	281.110	242.046	1015.033	181.200	913.579	93.941	505.812
and percentage transition (from year t to t+1)	0.031	0.204	0.027	0.145	0.075	0.320	0.055	0.284	0.042	0.206
Transition from suitable unused land to forest (ha)	23.237	284.792	5.185	194.381	44.372	585.723	29.815	380.645	24.579	453.368
and percentage transition (from year t to t+1)	0.007	0.110	0.003	0.092	0.012	0.230	0.006	0.123	0.010	0.199
Transition from high quality farmland to horticulture (ha)	-3.535	111.059	8.331	313.309	14.623	114.641	12.935	254.737	1.072	78.331
and percentage transition (from year t to t+1)	-0.005	0.098	0.006	0.271	0.006	0.065	0.003	0.210	0.001	0.070
Transition from low quality farmland to horticulture (ha)	0.827	167.696	20.229	439.951	25.826	186.717	14.659	333.724	17.106	193.747
and percentage transition (from year t to t+1)	0.001	0.106	0.016	0.378	0.012	0.111	0.010	0.282	0.009	0.114
Transition from suitable unused land to horticulture (ha)	2.365	58.134	0.487	62.454	9.611	99.125	3.471	37.640	6.079	102.998
and percentage transition (from year t to t+1)	0.001	0.029	0.000	0.033	0.003	0.036	0.001	0.015	0.002	0.044
Transition from high quality farmland to pasture (ha)	-2.453	47.026	-0.067	1.631	-20.985	210.574	-19.033	195.639	-0.102	5.719
and percentage transition (from year t to t+1)	-0.001	0.012	-0.000	0.001	-0.003	0.033	-0.003	0.031	-0.000	0.002
Transition from low quality farmland to pasture (ha)	0.100	254.357	0.303	22.532	163.017	1620.270	130.601	1486.406	4.549	128.457
and percentage transition (from year t to t+1)	0.001	0.064	0.000	0.009	0.040	0.394	0.033	0.361	0.001	0.038
Transition from suitable unused land to pasture (ha)	15.037	763.894	-10.419	449.723	-455.730	9763.926	-361.634	8915.194	-10.695	327.211
and percentage transition (from year t to t+1)	0.003	0.154	-0.005	0.231	-0.065	1.176	-0.049	1.080	-0.005	0.153
High quality farmland at year t (ha)	26260.707	21717.318	24838.133	23470.880	16863.310	22133.513	23277.455	25026.087	20980.215	20321.570
Low quality farmland at year t (ha)	38817.926	60341.432	27763.685	27149.048	37346.065	42890.698	46771.106	58792.367	24560.651	27210.216
Horticultural land at year t (ha)	5297.683	7102.855	3307.393	4217.050	2236.908	3147.473	2882.464	5242.841	4183.116	5150.230
Forestland at year t (ha)	7640.616	14833.012	4986.585	6969.766	6535.542	12987.912	4229.073	9619.559	8679.638	14388.325
Rural labor density at year t (person/ha)	2.540	2.160	2.427	1.941	1.256	4.237	2.003	1.912	1.982	4.044
Output of fruits per horticultural land at year t (ton/ha)	3.289	29.893	3.415	9.623	2.833	13.515	3.920	25.960	2.394	11.813
Output of forestry per forestland at year t ($10k/ha)	0.013	0.076	0.005	0.030	0.006	0.092	0.011	0.066	0.005	0.083
Output of livestock per pasture at year t ($10k/ha)	93.263	1010.221	921.906	12432.412	5.081	67.662	474.059	9035.785	77.720	918.509
Output of grain per farmland at year t (ton/ha)	5.049	5.541	5.216	2.439	2.657	2.562	3.342	4.678	4.871	3.061
Urban land value at year t ($10k/ha)	2.938	2.911	1.806	1.684	1.208	1.557	1.463	1.744	2.409	2.587
Local governmental revenue	1815.165	1987.514	1453.668	1238.783	800.387	1499.089	1093.632	1595.452	1442.017	1735.281
Local governmental expenditure	2798.927	2327.507	2412.201	1787.198	1874.545	1722.178	1981.590	1967.786	2559.038	1983.220
N	2805		2129		3343		4032		4245	

$$a_{jkit} = \beta_{0i}^{jk}(GfG_{it} \cdot region_i) + \boldsymbol{\beta_A^{jk} A_{it}} + \boldsymbol{\beta_X^{jk} X_{it}} + e_i + e_t + e_{it}$$

Table 2: Land Transition to Forests in China from 1996 to 2003 (in hectare)

		Land Transition					
		level farmland	erodible farmland	suitable unused land	level farmland	erodible farmland	suitable unused land
Model	Variable	to timber-producing forest			to orchards		
Pooled	GfG	74.13***	272.8***	28.82	-15.78*	16.43*	8.866*
		(14.79)	(31.64)	(20.75)	(7.476)	(7.197)	(3.793)
Regional	GfG·N	42.29***	464.9***	40.98	-15.79	25.78**	9.312*
		(5.664)	(40.93)	(26.04)	(9.105)	(9.319)	(4.738)
	GfG·S	13.50*	119.3**	18.54	-15.77	8.769	8.470
		(5.811)	(37.79)	(24.65)	(9.489)	(8.677)	(4.555)
Subregional	GfG·NW	84.08***	447.9***	30.88	-20.19	18.61	10.00
		(9.115)	(53.63)	(34.48)	(11.79)	(12.22)	(6.396)
	GfG·NC	20.99	176.6*	49.90	2.092	8.934	10.98
		(13.35)	(79.30)	(47.59)	(17.25)	(17.95)	(8.664)
	GfG·NE	35.13**	723.9***	48.36	-23.18	54.81***	7.002
		(12.15)	(71.75)	(41.99)	(15.73)	(16.42)	(7.593)
	GfG·SW	-2.101	94.57*	-3.501	0.630	23.70*	4.390
		(8.818)	(44.25)	(29.96)	(11.38)	(10.26)	(5.608)
	GfG·SC	53.14***	186.1***	17.30	-43.54**	-10.35	10.61
		(10.74)	(50.42)	(32.92)	(13.93)	(11.63)	(6.097)
	N	8566	9003	10012	8564	8949	9838

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Pooled, regional, and subregional models are separate regressions.

$$a_{jkit}/A_{ji,t-1} = \beta_{0i}^{jk}(GfG_{it} \cdot region_i) + \boldsymbol{\beta_A^{jk} A_{it}} + \boldsymbol{\beta_X^{jk} X_{it}} + e_i + e_t + e_{it}$$

Table 3: Land Transition to Forests in China from 1996 to 2003 (in share)

		Land Transition					
		level farmland	erodible farmland	suitable unused land	level farmland	erodible farmland	suitable unused land
Model	Variable	to timber-producing forest			to orchards		
Pooled	GfG	0.00233***	0.0152***	0.0195	-0.000241	0.00328*	0.000837
		(0.000652)	(0.00133)	(0.0109)	(0.000284)	(0.00152)	(0.00463)
Regional	GfG·N	0.00483*	0.0203***	0.0170	-0.000472	0.00462*	0.0000415
		(0.00216)	(0.00271)	(0.0139)	(0.000348)	(0.00203)	(0.00585)
	GfG·S	-0.000875	0.0138***	0.0215	0.00000758	0.00235	0.00150
		(0.00150)	(0.00156)	(0.0128)	(0.000358)	(0.00179)	(0.00549)
Subregional	GfG·NW	0.00199***	0.0162***	0.0154	-0.000525	0.00781**	0.00146
		(0.000544)	(0.00246)	(0.0189)	(0.000460)	(0.00286)	(0.00812)
	GfG·NC	0.000452	0.00630*	0.00129	-0.000368	0.000180	-0.00101
		(0.000769)	(0.00321)	(0.0252)	(0.000649)	(0.00370)	(0.0106)
	GfG·NE	0.00450***	0.0261***	0.0302	-0.000507	0.00373	-0.00113
		(0.000701)	(0.00293)	(0.0219)	(0.000593)	(0.00341)	(0.00915)
	GfG·SW	0.0000402	0.00152	0.0131	0.000620	0.00269	-0.000469
		(0.000508)	(0.00179)	(0.0156)	(0.000428)	(0.00212)	(0.00675)
	GfG·SC	0.00273***	0.0327***	0.0308	-0.000993	0.00177	0.00358
		(0.000619)	(0.00204)	(0.0171)	(0.000524)	(0.00240)	(0.00734)
	N	8363	8685	9566	8361	8631	9392

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Pooled, regional, and subregional models are separate regressions.

$$a_{jkit} = \beta_{0i}^{jk}(GfG_{it} \cdot region_i) + \beta_{1i}^{jk}(GfG_{it} \cdot region_i \cdot farmland\_value_{jit}) + \boldsymbol{\beta_A^{jk} A_{it}} + \boldsymbol{\beta_X^{jk} X_{it}} + e_i + e_t + e_{it}$$

Table 4: Estimated Breakeven Farmland Values (ton/ha) for Unintended Conversion to Timber-producing Forest

Model		Land Type	
		Level Farmland	Erodible Farmland
Pooled		10.262***	6.178***
		[5.58,14.94]	[4.82,7.54]
Regional	Northern	9.012***	5.246***
		[5.84,12.19]	[4.47,6.02]
	Southern	-7.437	5.865***
		[-39.85,24.97]	[3.46,8.27]
Subregional	Northwestern	5.676***	5.538*
		[3.89,7.46]	[1.16,9.91]
	Northcentral	10.593***	6.548***
		[6.16,15.03]	[4.90,8.19]
	Northeastern	11.516*	4.964***
		[0.72,22.32]	[4.59,5.34]
	Southwestern	1.569	3.547***
		[-14.45,17.59]	[1.61,5.48]
	Southcentral	3.381	6.374***
		[-2.70,9.46]	[5.21,7.54]

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Delta Method is adopted to calculate the *95% CI*s.
Pooled, regional, and subregional models are separate regressions.

Table 5: Land Transition to Forests in China from 1996 to 2003 with Interaction Terms

Model		Land Type	
		Level Farmland	Erodible Farmland
Pooled	GfG	113.2***	514.6***
		(18.69)	(78.56)
	GfG·farmland_value	-11.03***	-83.30***
		(3.241)	(19.40)
Regional	GfG·N	67.46***	949.6***
		(8.546)	(174.3)
	GfG·N·farmland_value	-7.485***	-181.0***
		(1.900)	(43.16)
	GfG·S	8.152	234.5***
		(8.843)	(60.75)
	GfG·S·farmland_value	1.096	-39.99**
		(1.412)	(14.03)
Subregional	GfG·NW	130.7***	622.9***
		(13.77)	(79.42)
	GfG·NW·farmland_value	-23.02***	-112.5
		(5.148)	(72.16)
	GfG·NC	128.0***	512.1**
		(37.40)	(184.5)
	GfG·NC·farmland_value	-12.09*	-78.21*
		(5.759)	(35.41)
	GfG·NE	64.17*	3059.0***
		(26.33)	(702.8)
	GfG·NE·farmland_value	-5.572	-616.2***
		(4.479)	(152.2)
	GfG·SW	1.813	219.0**
		(11.30)	(76.03)
	GfG·SW·farmland_value	-1.155	-61.74*
		(2.338)	(29.98)
	GfG·SC	-26.03	700.1***
		(45.94)	(156.6)
	GfG·SC·farmland_value	7.698	-109.8***
		(7.140)	(30.61)
	N	8363	8685

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Pooled, regional, and subregional models are separate regressions.

This is the table that used to derive the estimated breakeven farmland values.

Figure 1: Two Subsidizing Regions in the GfG Program

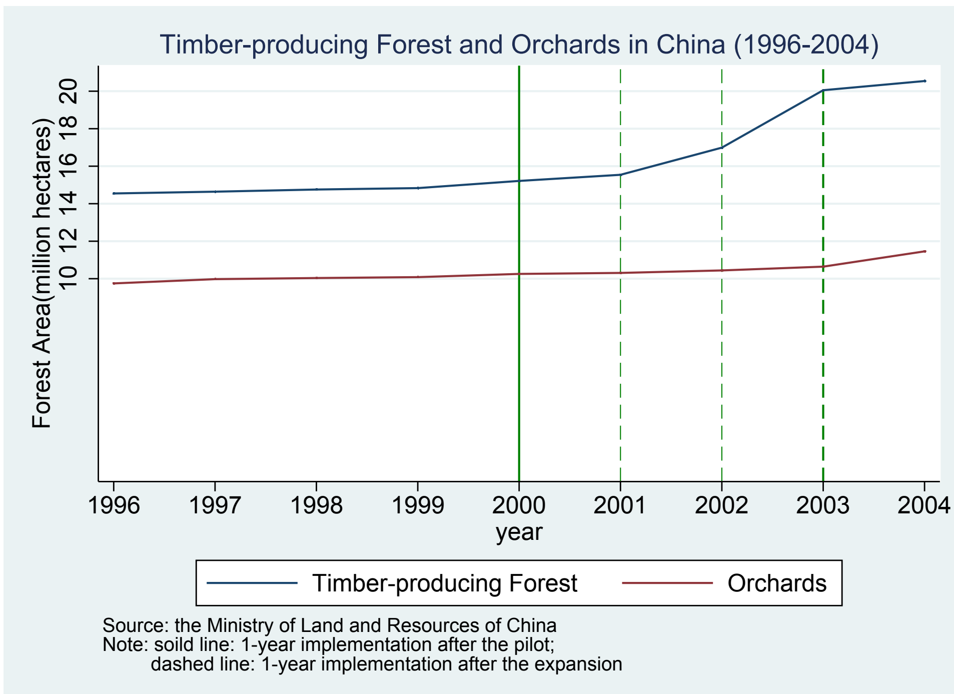

Figure 2: timber-producing forest and orchards Uses in China (1996-2004)

Figure 3: Western, Central, and East Coast Regions of China

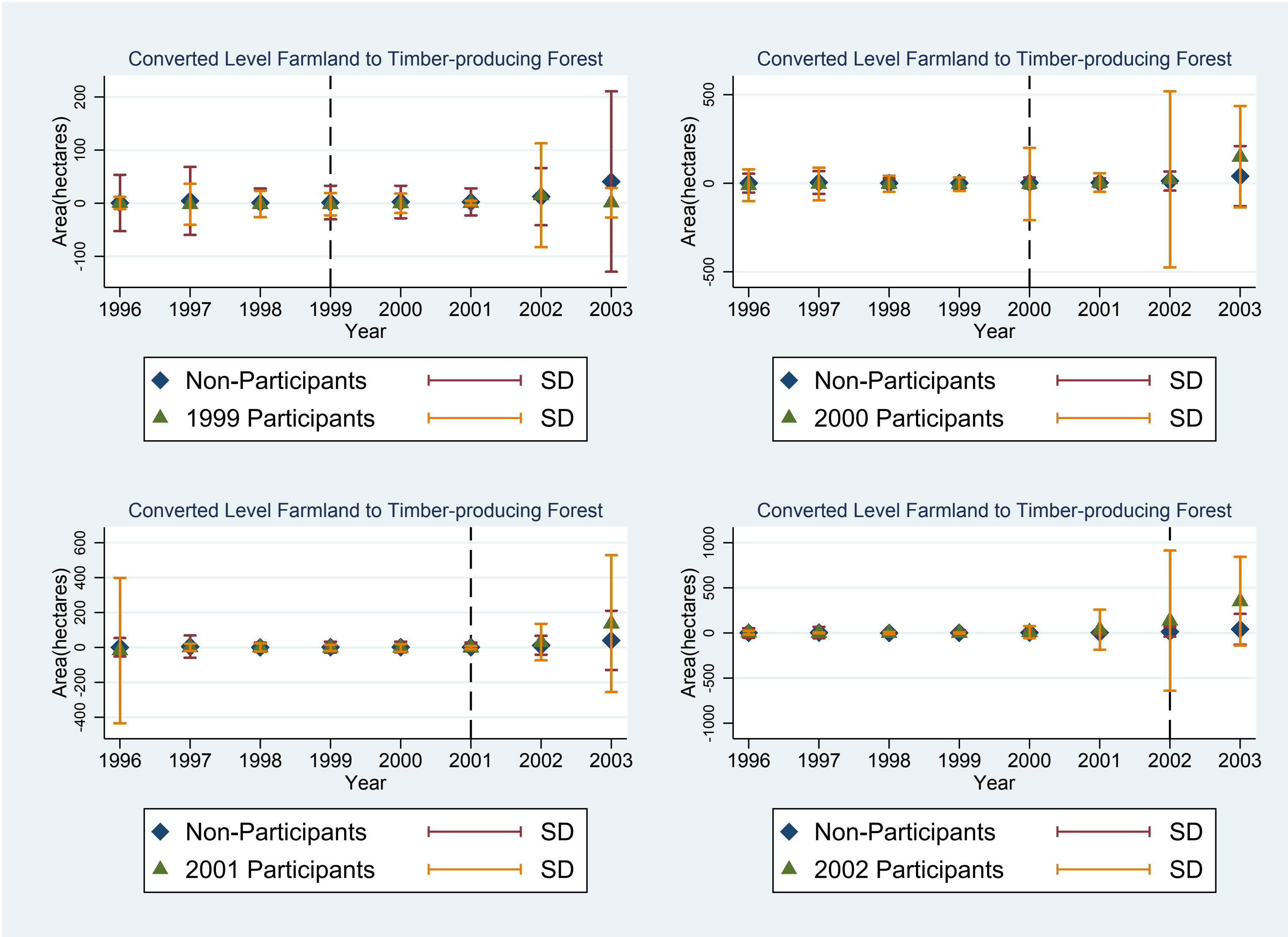

Figure 4: Comparison of Average Level Farmland Conversion to Timber-producing Forest

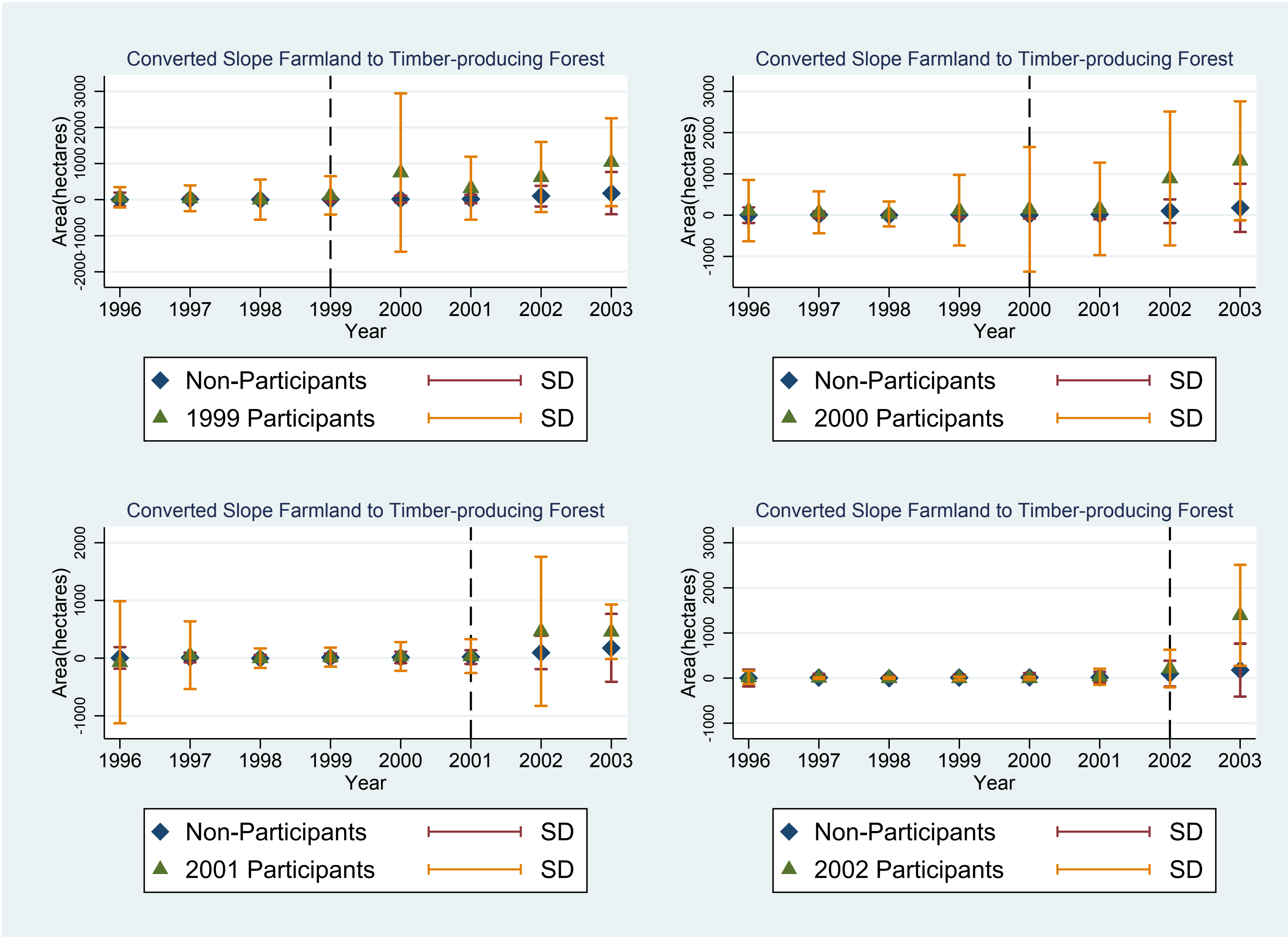

Figure 5: Comparison of Average Sloped Farmland Conversion to Timber-producing Forest

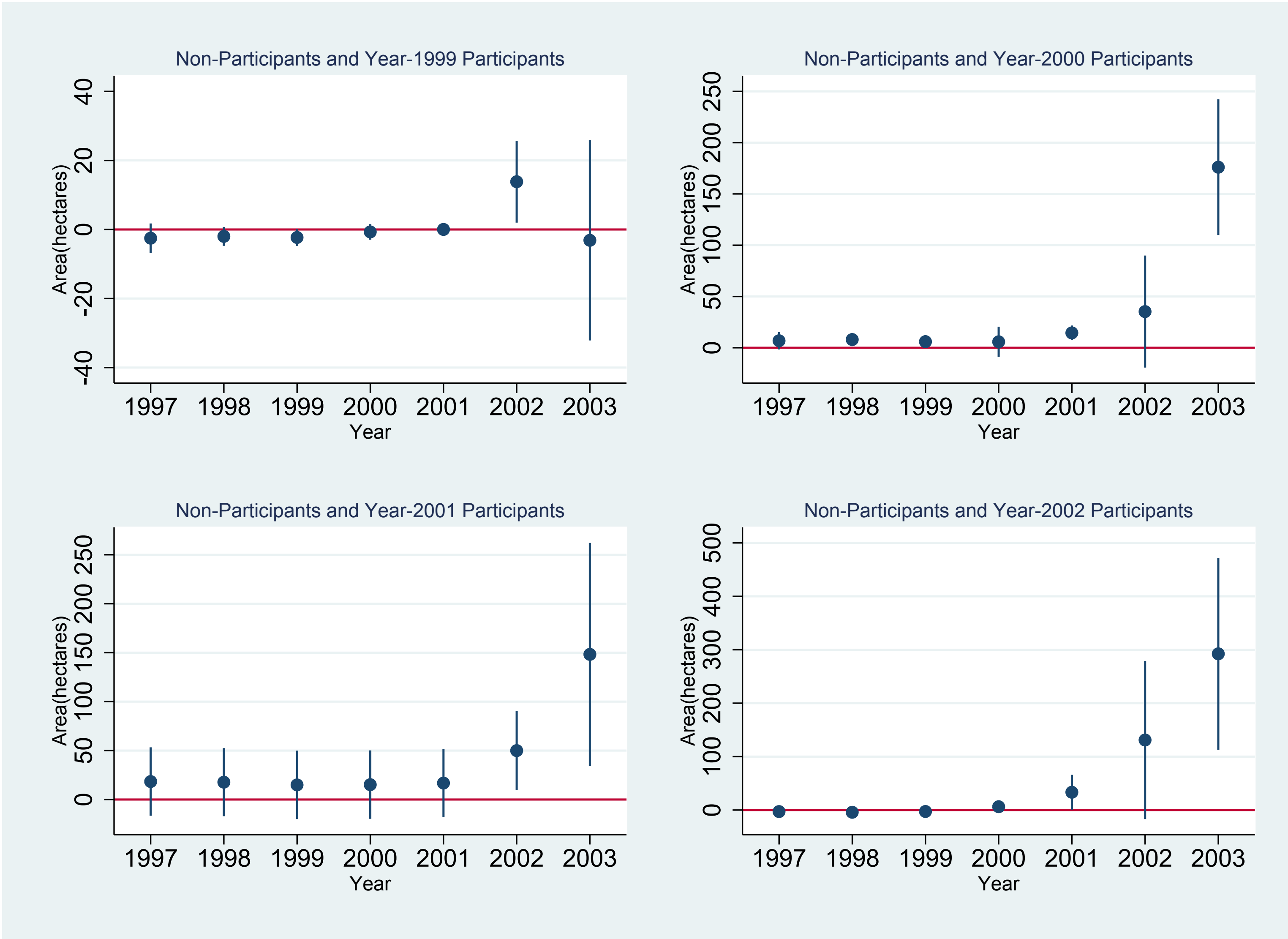

Figure 6: Placebo Treatment Effects for Level Farmland Conversion from Timber-producing Forest

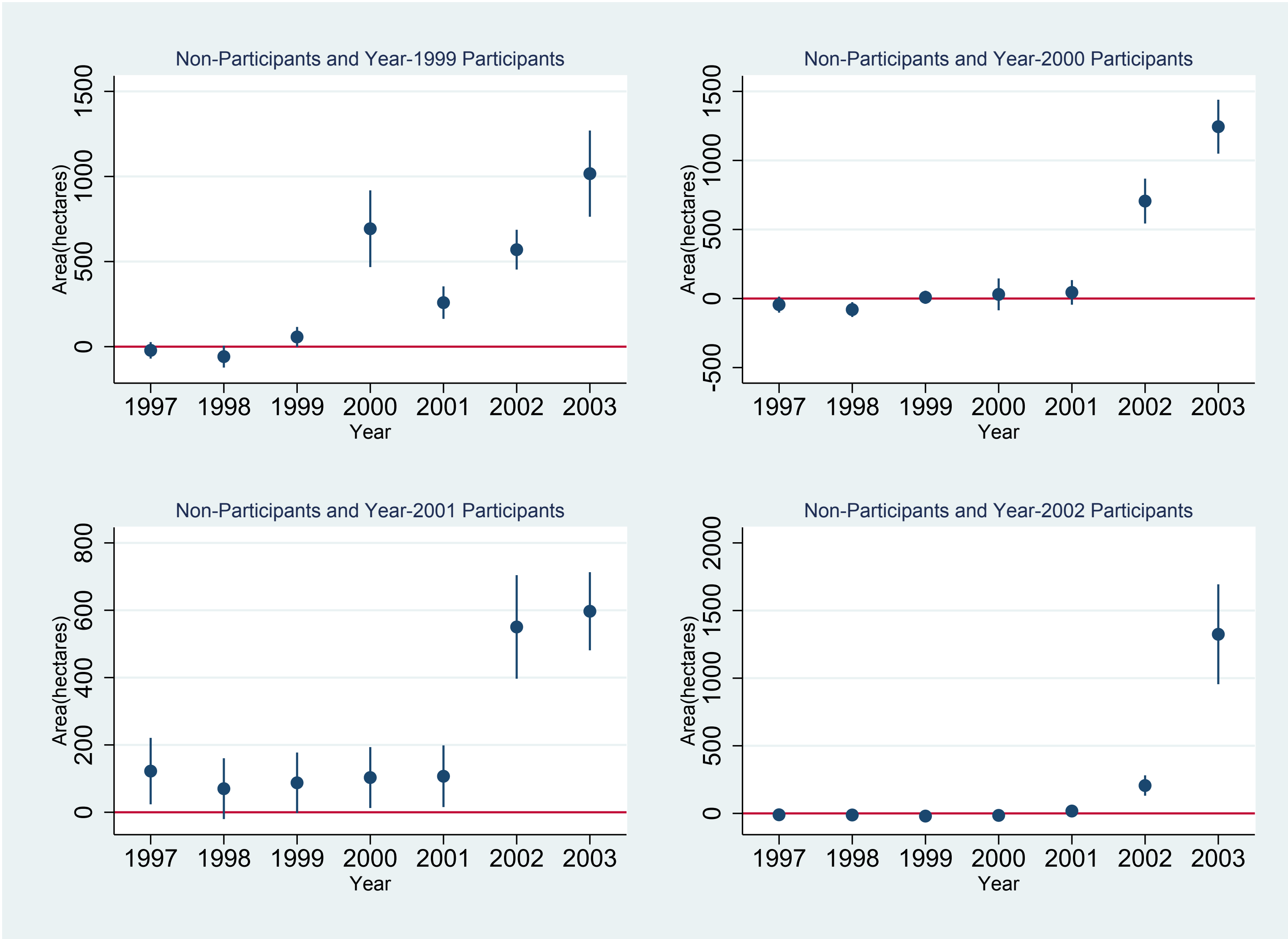

Figure 7: Placebo Treatment Effects for Sloped Farmland Conversion from Timber-producing Forest

Appendix I

To better understand how different driving forces across local areas influence land-use decision, a shifter is added to each function, which accounts for demographic-caused shocks that change the value of production or costs. With initial values of shifters to be 1 as in the maximization problem in Section 3, let $\alpha \geq 1$, $\beta \geq 1$, $\gamma \geq 1$, and $\omega \geq 1$ represent shifters for the value of forestry production, level farmland production, erodible farmland production, and the relative cost of erodible farmland conversion to level farmland conversion. The shifter in front of the function $C_l(a_l)$ is normalized to 1.

The benefit maximization problem under the afforestation process with interior solutions when $0 < a_l^* < A_l$ and $0 < a_e^* < A_e$ becomes:

$$\max V(a_l, a_e) = \alpha B(F + a_l + \varepsilon a_e) + \beta \pi_l (A_l - a_l) + \gamma \pi_e (A_e - a_e) - C_l(a_l) - \omega C_e(a_e) + S \cdot (a_l + a_e)$$

Applying Cramer's Rule yields the following comparative statics of a_l^* and a_e^* with respect to the model parameters. Let $g = \begin{pmatrix} \alpha B' - \beta \pi_l' - C_l' + S \\ \alpha \varepsilon B' - \gamma \pi_e' - \omega C_e' + S \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$, and variables $x = (a_l, a_e)$ with parameters $\theta = (F, A_l, A_e, \alpha, \beta, \gamma, \omega, S)$. The determinant of $Dg_x(\theta) = \alpha B''(\gamma \pi_e'' - \omega C_e'') + \varepsilon^2 \alpha B''(\beta \pi_l'' - C_l'') + (\gamma \pi_e'' - \omega C_e'')(\beta \pi_l' - C_l'') > 0$, which is guaranteed by the second-order sufficient conditions for a maximum, i.e., $g_{11} = \alpha B'' + \beta \pi_l'' - C_l'' < 0$, and $g_{22} = \varepsilon^2 \alpha B'' + \gamma \pi_e'' - \omega C_e'' < 0$.

The following results are the comparative statics with respect to:

F: $\dfrac{\partial a_l}{\partial F} = \alpha B''(\omega C_e'' - \gamma \pi_e'')/det < 0,$ $\dfrac{\partial a_e}{\partial F} = \varepsilon \alpha B''(C_l'' - \beta \pi_l'')/det < 0$

A_l: $\dfrac{\partial a_l}{\partial A_l} = \beta \pi_l''(\varepsilon^2 \alpha B'' + \gamma \pi_e'' - \omega C_e'')/det > 0,$ $\dfrac{\partial a_e}{\partial A_l} = -\beta \pi_l''(\varepsilon \alpha B'')/det < 0$

A_e: $\dfrac{\partial a_l}{\partial A_e} = -\gamma \pi_e''(\varepsilon \alpha B'')/det < 0,$ $\dfrac{\partial a_e}{\partial A_e} = \gamma \pi_e''(\alpha B'' + \beta \pi_l'' - C_l'')/det > 0$

α: $\dfrac{\partial a_l}{\partial \alpha} = B'(\omega C_e'' - \gamma \pi_e'')/det > 0,$ $\dfrac{\partial a_e}{\partial \alpha} = \varepsilon B'(C_l'' - \beta \pi_l'')/det > 0$

β: $\dfrac{\partial a_l}{\partial \beta} = \pi_l'(\varepsilon^2 \alpha B'' + \gamma \pi_e'' - \omega C_e'')/det < 0,$ $\dfrac{\partial a_e}{\partial \beta} = -\pi_l'(\varepsilon \alpha B'')/det > 0$

γ: $\dfrac{\partial a_l}{\partial \gamma} = -\pi_e'(\varepsilon \alpha B'')/det > 0,$ $\dfrac{\partial a_e}{\partial \gamma} = \pi_e'(\alpha B'' + \beta \pi_l'' - C_l'')/det < 0$

ω: $\dfrac{\partial a_l}{\partial \omega} = -C_e'(\varepsilon \alpha B'')/det > 0,$ $\dfrac{\partial a_e}{\partial \omega} = C_e'(\alpha B'' + \beta \pi_l'' - C_l'')/det < 0$

S: $\dfrac{\partial a_l}{\partial S} = [\varepsilon(1-\varepsilon)\alpha B'' + (\omega C_e'' - \gamma \pi_e'')]/det,$ $\dfrac{\partial a_e}{\partial S} = [-\alpha B''(1-\varepsilon) + C_l'' - \beta \pi_l'']/det > 0$

Appendix II

This section includes main estimated coefficients of the robustness check regressions. Panel 1 to 4 report the results of changing the identification of $farmland\_value$ from output grain/ha to GDP of primary industry/ha, value added of primary industry/ha, output value of farm/ha, and output of grain/ha, respectively. Panel 5 to 8 report the results of dropping the top 5% and 10%, and bottom 5% and 10% of the transitional observations, respectively. Because timber-producing forest afforestation is the main focus of the paper, each panel reports only the estimated coefficients of the GfG indicator in timber-forest conversion for the pooled and regional disaggregated (interact with north and south only) models. Table A1 and Table A2 show the estimated coefficients in the absolute value model and share model, respectively.

Table A1: Land Transition to Forests in China from 1996 to 2003 (in hectare)

Model	Variable	Land Transition					
		level farmland	erodible farmland	suitable unused land	level farmland	erodible farmland	suitable unused land
		Panel 1			Panel 5		
Pooled	GfG	74.50***	264.5***	29.49	80.74***	209.0***	23.86
		(14.71)	(31.23)	(20.49)	(16.21)	(32.26)	(21.58)
Regional	GfG·N	40.96***	437.9***	41.94	43.78***	406.1***	46.20
		(5.571)	(39.96)	(25.46)	(6.009)	(41.86)	(26.96)
	GfG·S	13.50*	118.7**	18.41	15.92*	51.29	3.413
		(5.765)	(37.59)	(24.51)	(6.286)	(38.63)	(26.17)
	N	8653	7703	8474	8130	7110	7930
		Panel 2			Panel 6		
Pooled	GfG	74.99***	263.5***	29.36	70.55***	234.9***	9.917
		(14.67)	(31.24)	(20.51)	(16.08)	(33.39)	(21.65)
Regional	GfG·N	41.36***	438.4***	41.91	41.20***	429.3***	12.81
		(5.571)	(39.96)	(25.47)	(6.025)	(42.11)	(26.47)
	GfG·S	13.28*	116.2**	18.14	12.41*	66.88	7.237
		(5.763)	(37.61)	(24.55)	(6.133)	(40.06)	(25.83)
	N	8648	7701	8472	8046	7157	7834
		Panel 3			Panel 7		
Pooled	GfG	78.12***	272.3***	25.92	93.59***	189.6***	28.15
		(14.81)	(31.33)	(20.61)	(16.82)	(35.52)	(23.20)
Regional	GfG·N	41.40***	446.5***	38.51	46.51***	398.2***	50.49
		(5.604)	(40.10)	(25.60)	(6.181)	(44.91)	(28.82)
	GfG·S	13.55*	125.7***	14.76	17.93**	-5.206	6.093
		(5.800)	(37.72)	(24.62)	(6.506)	(43.80)	(28.69)
	N	8644	7695	8466	7753	6550	7445
		Panel 4			Panel 8		
Pooled	GfG	74.87***	270.6***	30.67	74.44***	220.8***	4.851
		(14.82)	(31.64)	(20.84)	(14.87)	(36.18)	(22.01)
Regional	GfG·N	42.13***	460.1***	43.28	41.43***	427.6***	10.25
		(5.653)	(40.94)	(26.08)	(5.665)	(45.09)	(26.93)
	GfG·S	13.53*	119.4**	19.98	12.78*	34.35	-0.0548
		(5.805)	(37.78)	(24.71)	(5.732)	(43.53)	(26.14)
	N	8573	7628	8396	7753	6571	7428

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Pooled and regional models are separate regressions.

Table A2: Land Transition to Forests in China from 1996 to 2003 (in share)

Model	Variable	Land Transition					
		level farmland	erodible farmland	suitable unused land	level farmland	erodible farmland	suitable unused land
		Panel 1			Panel 5		
Pooled	GfG	0.00228***	0.0156***	0.0193	0.00251***	0.0107***	0.0185
		(0.000649)	(0.00137)	(0.0108)	(0.000717)	(0.000957)	(0.0117)
Regional	GfG·N	0.00278	0.0176***	0.0167	0.00287	0.0121***	0.0168
		(0.00147)	(0.00183)	(0.0137)	(0.00157)	(0.00130)	(0.0148)
	GfG·S	-0.000907	0.0143***	0.0214	-0.000888	0.00974***	0.0200
		(0.00150)	(0.00161)	(0.0128)	(0.00164)	(0.00112)	(0.0140)
	N	8379	7353	8091	7927	6819	7575
		Panel 2			Panel 6		
Pooled	GfG	0.00229***	0.0156***	0.0192	0.00219**	0.0144***	0.00492***
		(0.000649)	(0.00137)	(0.0108)	(0.000703)	(0.00141)	(0.00139)
Regional	GfG·N	0.00278	0.0175***	0.0167	0.00261	0.0169***	0.00295
		(0.00147)	(0.00183)	(0.0137)	(0.00157)	(0.00185)	(0.00172)
	GfG·S	-0.000858	0.0142***	0.0213	-0.00108	0.0126***	0.00661***
		(0.00150)	(0.00161)	(0.0128)	(0.00159)	(0.00166)	(0.00164)
	N	8374	7351	8089	7843	6866	7482
		Panel 3			Panel 7		
Pooled	GfG	0.00231***	0.0156***	0.0195	0.00282***	0.00744***	0.0194
		(0.000653)	(0.00137)	(0.0109)	(0.000666)	(0.000873)	(0.0127)
Regional	GfG·N	0.00271	0.0176***	0.0168	0.00281	0.0114***	0.0182
		(0.00147)	(0.00183)	(0.0137)	(0.00168)	(0.00115)	(0.0160)
	GfG·S	-0.000958	0.0143***	0.0216	-0.000832	0.00440***	0.0206
		(0.00151)	(0.00161)	(0.0128)	(0.00176)	(0.00104)	(0.0155)
	N	8377	7351	8087	7550	6259	7090
		Panel 4			Panel 8		
Pooled	GfG	0.00229***	0.0153***	0.0195	0.00227***	0.0136***	0.00447**
		(0.000653)	(0.00133)	(0.0110)	(0.000655)	(0.00153)	(0.00141)
Regional	GfG·N	0.00279	0.0174***	0.0169	0.00264	0.0163***	0.00273
		(0.00147)	(0.00179)	(0.0139)	(0.00147)	(0.00198)	(0.00175)
	GfG·S	-0.000870	0.0138***	0.0215	-0.000959	0.0115***	0.00594***
		(0.00150)	(0.00156)	(0.0129)	(0.00148)	(0.00181)	(0.00166)
	N	8363	7333	8037	7563	6280	7077

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Pooled and regional models are separate regressions.