Prices, Land Tenure Institutions, and Geography: A Matching Analysis of Farmland Abandonment in Post-Socialist Eastern Europe

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ABSTRACT. *This paper uses remote sensing data from 1989 to 2000 to examine the impacts of price liberalization, land tenure, and biophysical characteristics on farmland abandonment in the border region of Poland, Slovakia, and Ukraine. Using regression analysis and matching estimators, we find that differences in biophysical characteristics, rather than in tenure systems, best explain the variation in abandonment rates within Poland. The difference in abandonment rates between Poland and Slovakia partially results from differences in land reform strategy, and abandonment in Ukraine takes a unique trajectory because of the incompleteness of the land reform and the lack of outside opportunities for residents.* (JEL Q15, R14)

I. INTRODUCTION

One cannot find a more fundamental expression of human impact upon the earth than the transformation of landscapes via land use. The composition of a landscape is an outcome of the interactions between environmental, economic, and institutional factors. Which of these factors dominates is often difficult to ascertain for two reasons: First, institutions evolve in response to environmental conditions (Ostrom 1990; Platteau 2000). Second, institutions, especially the ones most strongly impacting land use, such as land tenure, rarely change rapidly, and this makes it difficult to estimate their effect. In particular, it is unclear if environmental conditions can override policy interventions. This paper seeks to identify the effects of price liberalization and institutional change on farmland abandonment as farmers in Eastern Europe adjusted to the monumental developments brought upon them by the collapse of Socialism in 1989.

The collapse of Socialism provides a partial natural experiment, because it was rapid, it resulted in sweeping changes, and there was large variation in policies implemented across countries. In terms of land use, these changes caused widespread, but not uniform, abandonment of agricultural land throughout Eastern Europe. We exploit the variation in the organization of land tenure across the Eastern Carpathians, in the border region of Poland, Slovakia, and Ukraine, in order to examine the roles of market liberalization, land tenure institutions, and biophysical factors in driving abandonment rates and spatial patterns of abandonment across countries.

An institutional shift of the magnitude generated by the dissolution of the Soviet Bloc is clearly an isolated situation that is unlikely to be repeated. However, the topic is of general interest for two reasons. First, it creates an opportunity to examine changes in agricultural production behavior as a response to variation in policies which *are* likely to be replicated. In particular, market liberalization and tenure regularization are strongly promoted in many developing countries, with land reforms ongoing in South Africa, Honduras, and Brazil, among other countries (Simmons et al. 2010; Sikor and Muller 2009). It behooves society to understand the potential effects of these

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policies in a variety of settings. Analyzing the impact of the collapse of Socialism lends insight into the direction of changes generated by tenure reform and price liberalization, although the magnitude of impact from a less extreme policy is likely to be different. There has been considerable research arguing that the impact of liberalization will vary depending upon the institutional environment in which it takes place (see Aghion et al. 2008, among others), and empirical evidence shows substantial variation in economic outcomes among transition countries (Fischer, Sahay, and Vegh 1996; Campos and Coricelli 2002). The present paper reports cross- and within-country analyses of important production outcomes that give insight into both liberalization and tenure reform policies.

Second, the outcome analyzed in this paper, farmland abandonment, is of interest because it is a reflection of the countervailing forces of urbanization and the intensification of agricultural production, which push toward increased abandonment, versus increased population growth and demand, which are associated with conversion of nonfarmland to farmland. Farmland abandonment is also a phenomenon understudied by land use economists,[1] though it has widespread effects on ecosystem functioning, biodiversity, and the services ecosystems provide to humanity (DLG 2005; MacDonald et al. 2000; Kuemmerle et al. 2008, 2011; Müller et al. 2009; Silver, Ostertag, and Lugo 2000). The Carpathian mountain region, which is the focus of this study, is of special interest because it constitutes Europe's largest temperate forest ecosystem, is a biodiversity hotspot, and harbors unique, traditionally managed landscapes that have been lost in Europe's West (UNEP 2007). Much of the Carpathian's biodiversity is supported by these low-intensity land use systems (Baur et al. 2006; Palang et al. 2006; Elbakidze and Angelstam 2007). Since abandoned farmlands may revert back to forest or to agricultural land, understanding the spatial patterns and causes of abandonment is essential to assessing subsequent effects on ecosystem services (e.g., carbon sequestration) and biodiversity conservation.

This paper combines new remote sensing data on farmland abandonment across the Carpathians in Poland, Slovakia, and Ukraine spanning the period 1988 to 2000 (Kuemmerle et al. 2008, 2011) with biophysical characteristics and spatially explicit tenure information. These data allow us to use a combination of regression and matching estimators to examine the impact of price liberalization, tenure regime changes, and biophysical characteristics. We find that the majority of the farmland abandonment in Poland was driven by price liberalization, and that the observed variation in abandonment rates across historically private versus state-managed lands is entirely driven by differences in biophysical characteristics. In other words, state farms were generally located on land less suitable for farming. Abandonment rates on biophysically similar land in both systems are equivalent.

We also explore the roles of price liberalization and decollectivization in Slovakia and Ukraine, although these effects are less well identified than in the Polish case. Comparing Poland to Slovakia, the data show substantially more land abandonment in Slovakia, probably due to both superior labor market opportunities and difficulties in the implementation of the land reform. The results for Ukraine present something of a puzzle, for while price trends and anecdotes regarding the effectiveness of land reform suggest that abandonment should be highest there, it is in fact no different than abandonment in Polish privately held land. Examination of the available evidence suggests that this is a result of a high and increasing dependence on subsistence farming in this region. In fact, other work has shown abandonment within Ukraine outside of this region, where subsistence farming is less common, to be significantly higher (Baumann et al. 2011). Across regions, farmland distributions, conditional on geographic characteristics, are generally more similar in 2000 than in 1988, implying that the changes in tenure regimes released important constraints to efficient land allocation.

[1] Our literature search shows two papers published in economics journals on this specific topic: Sikor, Muller, and Stahl 2009 and Vranken, Noev, and Swinnen 2004.

FIGURE 1
Location of the Study Region in Europe *(left)* and Ownership Regime Prior to 1989 *(right)*
Source: Authors' calculations.

II. CONTEXT

We focus on the border region of Poland, Slovakia, and Ukraine in the northeastern Carpathians, a region of approximately 17,800 km^2 (see Figure 1). The region was part of the Austro-Hungarian Empire for a period of approximately 150 years until 1918, providing the three countries a common historical context. During that period, land use intensified markedly, mainly due to technological advancements and population growth (Turnock 2002; Augustyn 2004). The region's forests were largely converted to farmland during the late nineteenth and early twentieth centuries, particularly in mountain valleys and densely settled foothills and plains, whereas forests remained dominant in the montane zone (Turnock 2002). After the region reached a low point in forest cover during the 1920s, forests expanded as urbanization and industrialization progressed and marginal farmland was abandoned in response (Kozak, Estreguil, and Troll 2007; Kuemmerle et al. 2011).

During Socialist rule, great efforts were made to intensify agriculture in all three countries. However, land ownership and management differed among the Polish, Slovak, and Ukrainian regions of the study area. In Poland as a whole, most farmland was never collectivized (Lerman, Csaki, and Feder 2004). Yet many areas in the study region were state owned and managed, because these lands had been depopulated following border changes between the Soviet Union and Poland in 1947, and large-scale state-owned farming enterprises were established in these areas (Turnock 2002; Augustyn 2004). In Slovakia, almost all farmland was collectivized and managed in state-controlled cooperatives, but landowners retained property rights to their fields. This was different in Ukraine, where all land was owned by the state and managed in large-scale collectives or state farms (Lerman, Csaki, and Feder 2004).

After the dissolution of the Soviet Bloc, Slovakia, Poland, and Ukraine launched land reforms to privatize farmland and to individualize land use (Mathijs and Swinnen 1998). Land reform strategies were driven by a variety of factors, but in the countries in question largely depended upon a combination of pre-collectivization ownership patterns and the land ownership system in Socialist times (Swinnen 1999). Poland auctioned formerly state-owned farmland, Slovakia restituted farmland to previous owners, and Ukraine distributed farmland among the workers of the agricultural enterprises. In Ukraine, the redistribution of farmland has been accomplished through a "shares" system, and buying and selling of land has been severely restricted, although landowners choose how and what to produce (Lerman, Csaki, and Feder 2004).

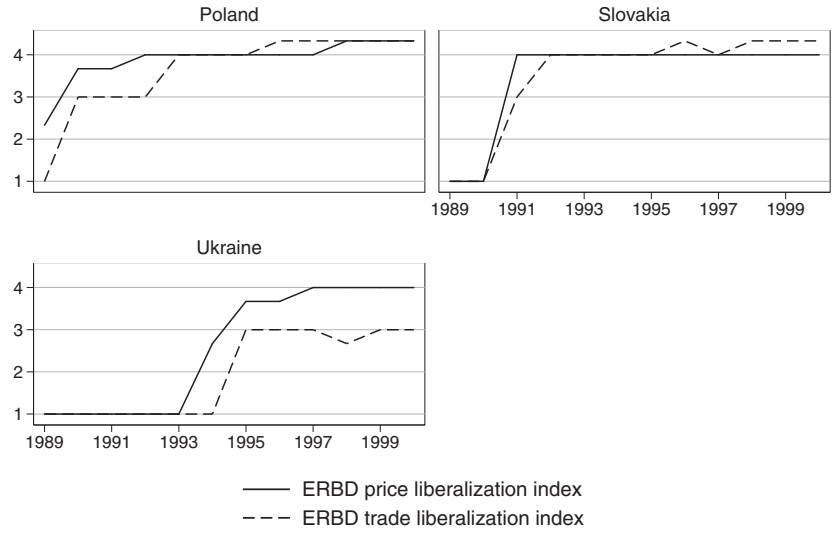

FIGURE 2
Trade and Price Liberalization in Study Countries
Source: European Bank for Reconstruction and Development 2011.

The Ukrainian land reform has progressed slowly and is incomplete, with efforts to complete redistribution stalling in the mid to late 1990s (Lerman 1999, 2001).

The countries also differ in their broader liberalization strategies. Poland and Slovakia joined the European Union (EU) in 2004, giving farmers access to subsidies provided under the Common Agricultural Policy. Ukraine, in contrast, remains outside the EU, and the establishment of the EU's eastern border further isolates the Ukrainian Carpathians. Although the latter events occurred after our study, the trajectory of integration of Poland and Slovakia into the EU was quite clear quite soon after 1990: Poland applied for EU accession in 1994 and Slovakia in 1996. Price and trade liberalization trends across countries are shown in Figure 2. Figure 3 illustrates the trends in wheat prices across the sample countries and years. While all prices showed similarly volatile trends, the variation in Slovakian prices was much less than that of the other two countries. In addition, prices were consistently lower in Ukraine. Shorter-term analyses of producer price trends in Poland and Ukraine by Valdes (1999) show similar trends: high volatility and consistently lower prices in Ukraine. By the end of the study period, all countries have similar prices and price liberalization indices, while Ukraine's trade liberalization trend and level are quite distinct from those of Poland and Slovakia.

III. CONCEPTUAL FRAMEWORK

Profit-maximization is not the appropriate decision-making framework in a centralized economy, where production choices are not made at the farm level, but rather depend on pre-set production goals, or are limited by fixed inputs. However, writing the components of "profits" allows us to compare outcomes across centralized and decentralized decision-making frameworks. These can be written as a function of production technology, inputs, and prices, although these prices may not be of direct concern to the individual farmer. We define inputs as land (T), labor (L), and capital (K), and prices for inputs and outputs, w and p, respectively. One can reasonably assume that land varies in quality, which we parameterize, for simplicity, with τ, where

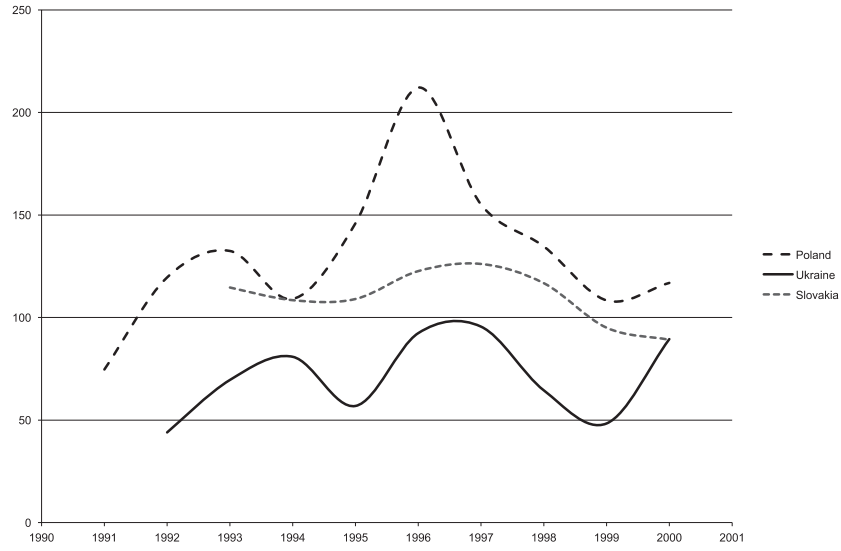

FIGURE 3
Wheat Price Trends across Sample Countries
Source: FAOSTAT 2010.

a higher value indicates higher-quality land. One can then write the profits as

$$pQ(\tau T,L,K) - c(w,\tau T,L,K),$$

where $Q(\cdot)$ is a production function and $c(\cdot)$ a cost function.

In a Socialist setting, Q, L, and K are fixed, with losses compensated for by government, so w and p do not matter to the individual farmer. The release of central planning and opening up of borders to trade implies that input and output prices are now determined by market forces, and the maximization of profits becomes a farmer's (or a collective's) concern. Inputs and outputs are no longer fixed, and the demand for land can be written: $T^{d} = T(\tau,p,w)$, with the function increasing in output and land quality and decreasing in input prices under standard production function assumptions. Whether or not we observe abandonment depends upon the initial area farmed, T^{0}, relative to the area farmed given post-Socialist prices and land quality. We define the latter equilibrium as T^{*}. Given that in our sample we observe no conversion of forest to farmland, we infer that $T^{0} > T^{*}$. Since one would expect demand for farmland to increase with decreases in output and increases in input prices, our data is consistent with the evidence presented by Rozelle and Swinnen (2004, 420) that "in the first five years of transition, for example, the ratio of output to input prices in agriculture fell more than 30% in Hungary, 50% in the Czech Republic, and at least 70% in Slovakia, Poland, Russia, Ukraine, and some of the Baltics."

The amount of abandonment clearly depends upon the extent of the implicit adjustment of "pretransition" to market prices. Fertilizer subsidies are often cited as one of the main sources of price distortion (Rozelle and Swinnen 2004), but abandonment must also depend critically on the ability of labor to find alternative employment in other sectors of the economy, a phenomenon that varies considerably across the countries in our sample. The rapidity of the adjustment of land inputs must also be a function of the tradability of land, and hence upon the tenure regime put in place and the effectiveness of governments in carrying out the privatization process. Finally, the quality of the land available to farmers will influence agricultural productivity and therefore abandonment.

Tenure regime explicitly enters the framework by establishing T^0. However, it also enters implicitly by affecting the ability of producers to reallocate land efficiently after the shift to a market economy. Variation in T^* across different tenure settings that is unexplained by land quality and prices suggests differences in land use efficiency caused by potential institutional frictions. The key drivers highlighted by this framework are therefore tenure regime, land quality, and input and output prices, particularly wages in the agricultural sector relative to other sectors in the economy.

IV. DATA DESCRIPTION

The study region, which straddles the borders of Poland, Slovakia, and Ukraine, is shown in Figure 1. The right part of this figure zooms in on the region of interest, showing the differences in tenure regimes prior to the dissolution of the Soviet Bloc. Important for our identification strategy is the heterogeneity in Socialist-era land ownership in Poland, which contained both private and state land prior to 1989, compared to the other two countries in the sample, in which agriculture was entirely collectivized (Slovakia) or nationalized (Ukraine).

Land cover and land use change maps for our study region were available from previous research (Kuemmerle et al. 2006, 2007, 2008). Farmland abandonment was mapped based on Landsat Thematic Mapper and Enhanced Thematic Mapper satellite images from 1986 and 1988 (representing the late Socialist period) and 2000 (representing the transition period). The resolution of the land cover maps was 30 m. We first masked all nonfarmland land covers (e.g., forests, settlements, or water bodies) and then separated farmland in use from abandoned areas using a multitemporal image classification (Kuemmerle et al. 2008). Farmland abandonment was defined as arable land or managed grassland that converted to permanent, unmanaged grasslands, fallow fields, successional shrubland, or young forest. The accuracy of our farmland abandonment map was validated using independent data collected in the field and from high-resolution air photos and satellite images, and was high (overall map accuracy = 91%).

To generate our outcome of interest, we summarized the data in a 1×1 km grid, and the unit of analysis is the grid cell. Percentage baseline farmland for each grid cell (heretofore "cell") and percentage abandoned land were calculated, with the final abandonment calculation being the ratio of the two. Across the study region, about 16% of all areas farmed during the last years of Socialism were abandoned by 2000. Abandonment rates and spatial patterns varied substantially across the region (Figure 4). For example, abandonment rates were notably higher in Slovakia and along the northern border of our study region in Ukraine.

We use road density as a measure of market connectedness. This measure is highly correlated with distance to cities, and therefore transport costs, but offers the additional nuance of capturing infrastructure development: higher road densities are associated with city proximity and better infrastructure. Road density measurements were extracted from official digital road maps. In Poland, the scale of the road map was 1:50,000, in Slovakia 1:100,000, and in Ukraine, 1:200,000 (Geodezkartinformatyka 1997). Road networks did not change substantially during the period studied.

Land quality was measured by a combination of variables. The Shuttle Radar Topography Mission was used as the elevation model[2] and to calculate the slope (in degrees) for each cell. Soil quality was extracted from a 1×1 km grid of categorical soil types obtained from the European Soils Database produced by the European Commission's Land Management and Natural Hazards Unit (European Soils Database 2011). The 16 categories in the database were reclassified into those that have "no restrictions for agriculture" and those with restrictions (e.g., stony soils). This generates a binary indicator for whether the soil is appropriate for agriculture.

Table 1 shows summary statistics for those cells of land that contained some amount of farmland in the last years of Socialism. There are considerable differences in covariates.

[2] ftp://srtm.csi.cgiar.org.

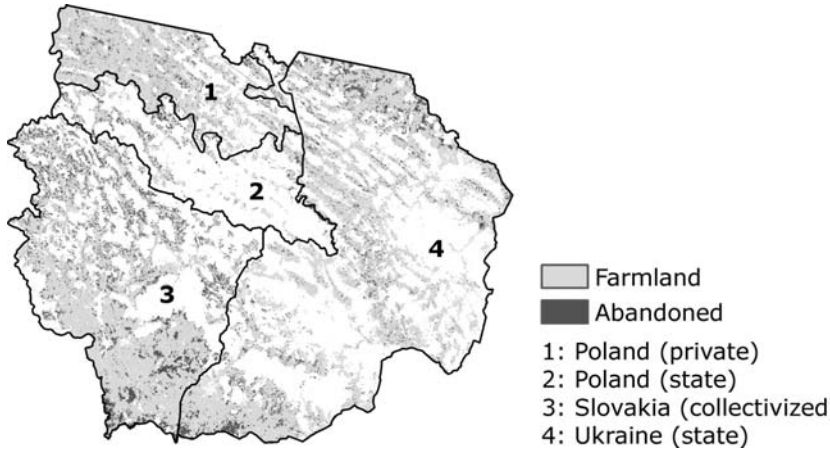

FIGURE 4
Baseline Farmland and Farmland Abandonment
Source: Authors' calculations.

TABLE 1
Summary Statistics: Average Values for Cells with Baseline Farmland > 0

Variable	Poland		Slovakia	Ukraine
	State	Private		
Mean elevation (meters)	577.1	389.7	276.4	519.0
Mean slope (degrees)	13.4	8.9	10.6	14.6
Road density (km/km^2)	0.490	0.771	0.612	0.368
Soil with no restrictions for agriculture	0.382	0.370	0.748	0.117
Baseline farmland (proportion)	0.599	0.668	0.644	0.533
Farmland abandoned (abandoned/baseline)	0.189	0.127	0.237	0.129

Source: Authors' own calculations.

Within Poland, state land is generally at higher elevations and has a significantly higher slope than private land, and road densities are lower. Slovakia (collective farms) has the lowest mean elevation and somewhat lower slopes than Ukrainian and Polish state land. Ukraine has the lowest road density. The largest concentration of soils unrestricted for agricultural use is located in Slovakia, followed by Poland and Ukraine. The highest farmland abandonment rate per cell is found in Slovakia, followed by state land in Poland. Without controlling for any geographic characteristics, abandonment rates in Ukraine are similar to those on private land in Poland.

Figure 5 shows the distribution of elevation and slope within the three countries of interest, estimated using kernel densities, and within the state and private regions of Poland. The distributions of these geographic characteristics within the study regions is quite distinct, although there is certainly overlap. The slope distributions of Ukraine and Slovakia are more similar, and there is a somewhat limited range of elevation overlap between private and state land in Poland. This overlap is essential for our empirical strategy, the underlying assumption of which is that one can locate pieces of land with nearly equivalent characteristics in different country/tenure combinations.

The three countries included in this study, while all transition economies, are quite different in baseline economic characteristics and in many subsequent indicators of economic development (see Table 2). Poland and

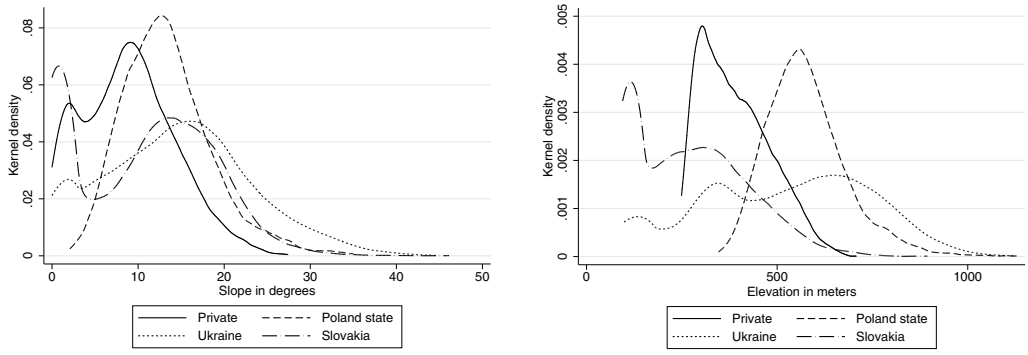

FIGURE 5
Distributions of Elevation and Slope by Country/Socialist Tenure Status

Source: Authors' calculations.

TABLE 2
Country-Level Characteristics

Indicator	Poland	Slovakia	Ukraine
Share of agricultural employment, 1989	26.4	12.2	19.5
GNP/capita, US$ 1989	5,150	7,600	5,680
Labor/land	0.258	0.139	0.118
Years of central planning[a]	41	42	74
Share of individual land use, 1990	77	5	7
Share of individual land use, 1997	82	11	17
GDP growth, 1992–1997	5.79	4.14	− 12.74
Agricultural production growth, 1992–1997	1.44	0.54	− 6.01
% change agricultural employment 1989–2000	− 25.7	− 45.1	22.5

Source: Lerman 2000 and World Bank 2011.
[a] Western Ukraine, which contains our study region, joined the Soviet Union only after 1945 and thus has a similar number of years of central planning as Poland and Slovakia, running from 1945 to 1991, rather than 1945 to 1989, as in Poland and Slovakia.

Slovakia had fairly similar economic growth trends in the post-Socialist period, while Ukraine's GDP and agricultural growth faltered significantly in the 1992–1997 period. While both Poland and Slovakia had significant decreases in the percentage of total employment in agriculture, Ukraine's percent employment in agriculture increased substantially from 1989 to 2000. On the other hand, Ukraine and Poland began with similar levels of GDP per capita, and Slovakia and Ukraine were quite close in terms of individual land use both in 1990 and 1997, relative to Poland, which started off with a much higher proportion of land in private hands. We shall keep these contrasts in mind as we proceed through the empirical analysis.

V. EMPIRICAL ANALYSIS: REGRESSION

We begin the empirical analysis with a standard regression framework to analyze correlations across all countries and then proceed to use matching in order to generate more credible comparisons both within and between countries. This section discusses the specifications of and results from the simple regression strategy, while Section VI discusses and implements a matching estimator.

Regression Framework

Although our primary outcome of interest is farmland abandonment, the initial and final

distributions of farmland also provide interesting insights. We therefore analyze all three outcomes: baseline farmland, farmland abandonment, and the final distribution of farmland. For abandonment, the measure is the percentage of farmland abandoned out of the total farmland in a given cell i in country/tenure system c in 1989. Denoting agricultural land outcomes with A, we assume the relationship between it and geographical variables (G_i) as

$$A_{ic} = \alpha + G_i'\beta + C_c'\gamma + CG_{ic}'\pi + \varepsilon_{ic},$$

where a dummy variable, C, is included for Ukraine, Slovakia, and Poland private land, with Poland state land being the omitted category. Interaction terms between the geographical variables (slope, elevation, baseline farmland, soil quality, and road density) and country/tenure dummies (CG) allow for variation in response to biophysical characteristics by country. The parameters to be estimated are α, β, γ, and π. The fact that there is not farmland or not abandonment in a significant number of cells creates a substantial number of zeros in the data. In order to address this censoring problem, we estimate all equations using a tobit, and standard errors are clustered at the country level. Cells that have no farmland in the baseline year are dropped from the abandonment estimation.[3]

Regression Results

Table 3 shows results from three tobit regressions. Column (1) analyzes the distribution of farmland prior to 1989, Column (2) farmland abandonment between 1989 and 2000, and Column (3) the distribution of farmland in 2000. The dependent variables in all cases are proportions. The table contains some intriguing correlations. Column (1) shows the similarity in the baseline distribution of farmland. In all countries and tenure systems, farmland is concentrated in cells of lesser slope, lower elevation, and higher road density. There is an odd correlation between the agricultural soil quality indicator and baseline farmland; there appears to be a lower density of farmland in cells without restrictions for agriculture in all regions except for state land in Poland. One interpretation of this could be that farms were inefficiently located during the Socialist period. Another possibility is that the 1×1 km average is too coarse to measure important local variation in soil quality. The baseline distribution of Ukrainian farmland is somewhat less sensitive to elevation and slope than land in any of the other countries.

The process of abandonment appears to have proceeded differently in different countries (Column 2). In formerly state land in Poland and in Ukraine, higher elevation and steeper slopes are associated with *less* abandonment, which in the context of land use theory, is counterintuitive. Standard theory would suggest that higher elevations and steeper slopes would be associated with lower-value farmland and hence would increase abandonment, as we observe in Slovakia and in private land in Poland. However, while the finding for state land in Poland and in Ukraine is surprising, it is not inconsistent with the evidence presented by Müller et al. (2009) and Baumann et al. (2011), who suggest that there are fewer labor opportunities to pull individuals out of agriculture in these more remote areas.

In addition, it is possible that these high-elevation areas, particularly in Ukraine, were associated with subsistence agriculture. If market imperfections distorted price signals to these households, some may remain dedicated to subsistence agriculture even in the presence of large price fluctuations. Key, de Janvry, and Sadoulet's (2000) seminal paper on transactions costs and agricultural supply shows how this phenomenon could operate, using Mexico as an example. In their framework, fixed and/or proportional transactions costs place a wedge between buyer and seller prices, and there can be a wide range of prices over which production remains the same, responding only to household shadow prices. Finally, this correlation could be a cautionary tale for making

[3] As a robustness check to see if spatial autocorrelation is driving the results, we conduct several estimations using randomly selected subsets of the data. The rationale is that the random selection of parcels across space helps break correlation across space in the error terms. The results from these estimations are no different from those presented here and are available upon request.

TABLE 3
Tobit Estimation of Farmland Distribution and Abandonment

	Dependent Variable		
Covariate	Farmland Pre-1989 (1)	Abandonment (2)	Farmland in 2000 (3)
Elevation	−0.00107***	−0.000385***	−0.000152***
	(3.52e−05)	(1.06e−05)	(2.50e−05)
Elevation × Ukraine	0.000766***	0.000278***	0.000187***
	(3.04e−05)	(1.11e−05)	(2.28e−05)
Elevation × Slovakia	3.01e−06	0.000820***	−7.37e−05***
	(8.39e−06)	(1.32e−05)	(9.70e−06)
Elevation × Private land Poland	−0.000283***	0.000395***	0.000204***
	(2.43e−05)	(1.14e−05)	(1.98e−05)
Slope	−0.0320***	−0.00715***	−0.00140***
	(0.000573)	(0.000147)	(0.000273)
Slope × Ukraine	0.00409***	0.00306***	0.00197***
	(0.000253)	(0.000105)	(0.000202)
Slope × Slovakia	0.0109***	0.0130***	−0.00222***
	(0.000672)	(0.000296)	(0.000487)
Slope × Private land Poland	0.00320***	0.00717***	0.000467
	(0.000477)	(0.000181)	(0.000297)
Road density	0.186***	−0.112***	0.0458***
	(0.00311)	(0.00131)	(0.00144)
Roads × Ukraine	−0.0647***	0.0338***	−0.00757***
	(0.00218)	(0.000211)	(0.00134)
Roads × Slovakia	−0.0716***	0.0581***	−0.0143***
	(0.00209)	(0.00107)	(0.00115)
Roads × Private land Poland	−0.0944***	0.0572***	−0.0168***
	(0.00285)	(0.000740)	(0.00148)
Baseline farmland		0.169***	0.818***
		(0.00673)	(0.00723)
Farmland × Ukraine		−0.130***	0.119***
		(0.000233)	(0.000116)
Farmland × Slovakia		−0.0844***	−0.0629***
		(0.00292)	(0.00107)
Farmland × Private land Poland		−0.176***	0.100***
		(0.00255)	(0.00397)
Agricultural soils (0/1)	0.00601***	−0.134***	0.0253***
	(0.00196)	(0.00171)	(0.00196)
Soils × Ukraine	−0.0914***	0.157***	−0.0319***
	(0.000801)	(0.00288)	(0.00151)
Soils × Slovakia	−0.0486***	0.120***	−0.0148***
	(0.000782)	(0.00179)	(0.00135)
Soils × Private land Poland	−0.0537***	0.110***	−0.0129***
	(0.00119)	(0.00118)	(0.00148)
Ukraine	−0.237***	−0.259***	−0.136***
	(0.0179)	(0.00948)	(0.0151)
Slovakia	−0.144***	−0.443***	0.0484***
	(0.0171)	(0.00944)	(0.0144)
Private land Poland	0.155***	−0.308***	−0.105***
	(0.0175)	(0.00739)	(0.0121)
Observations	17,175	13,628	17,175
Likelihood ratio chi-squared	16,189.55	2,560.24	41,667

Note: Tobit coefficients shown. Robust clustered standard errors in parentheses. Constant not shown.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

comparisons across very different geographical distributions of land quality: Ukraine and the formerly state land in Poland are typically at a higher elevation than the Slovakian or private Polish lands.

Across countries, land with good agricultural soils is significantly less likely to be abandoned in all countries, with the exception of Ukraine. Higher baseline percentage of farmland in a cell is associated with greater abandonment, and greater road density with less. Finally, the effect of more baseline farmland on abandonment is positive in formerly state-owned land in Poland and in Slovakia, while the opposite is true in Ukraine and in privately held land in Poland, where there appears to be more persistence of earlier farmland locational choices. We examine and discuss these correlations in more detail in subsequent sections.

Finally, Column (3) shows the correlations between biophysical characteristics and the distribution of farmland in 2000. As in the baseline, higher elevation and slope are associated with less farmland, and denser roads and better agricultural soils with more farmland. The differences in correlations between biosphysical characteristics and farmland density are consistently smaller in Column (3) than in Column (1), indicating convergence in farmland locational choice across countries. Ukraine still exhibits the somewhat unusual correlations with slope, elevation, and soil quality, although the magnitudes are smaller than in the baseline period. Overall, these results indicate differential but efficiency-improving farmland abandonment across countries, since abandonment generally seems to have occurred in places where agriculture was likely to have been less profitable. The final distribution of farmland also suggests that the abandonment process led to farmland being located on more fertile soils, although Ukrainian farmland is still found in unexpected places.

VI. EMPIRICAL ANALYSIS: MATCHING

Matching Framework

Given the variation in geographic characteristics across countries, in particular, the lack of overlap in slope and elevation measures (Figure 5), comparisons between all cells could lead to misleading results. In order to limit comparisons to pieces of land that are as similar as possible according to geographic characteristics, we make use of a matching procedure. Following Abadie et al. (2001) we define the observed outcome, Y, as

$$Y_i = Y_i(W_i) = \begin{cases} Y_i(0) \text{ if } W_i = 0 \\ Y_i(1) \text{ if } W_i = 1 \end{cases}.$$

For our purposes, the outcome of interest is land use or land use change in a particular grid cell. The "treatments" are tenure regimes. If assignment to treatment is random, it is trivial to estimate the difference between $Y_i(0)$ and $Y_i(1)$. However, we are faced with the problem that, while individuals did not have the choice of which tenure regime to participate in, the land that was placed in Socialist times in private and public ownership was placed there for a reason. For example, in Poland, state land is generally land that Poland acquired after World War II, and that had been depopulated due to border changes and resistance (Turnock 2002; Augustyn 2004). The Socialist government of Poland "repopulated" it with state agricultural workers, and it is clearly of lower quality than private land, according to our observable variables. The organization in land tenure and land privatization in Ukraine and Slovakia is also the result of historical processes unique to those places, although within these countries there is no evident variation of the type observed in Poland.

We are interested in an estimation that includes the information about how much of the private farmland would be abandoned *were it to have been in state hands,* and how much of the state land would have been abandoned *were it in private hands.* In other words, we would like to know the following:

$$\tau = \frac{1}{N} \sum_{i=1}^{N} \{ Y_i(1) - Y_i(0) \}.$$

However, we cannot know this. Therefore, we apply an estimator that predicts the counterfactual outcome for each group using information from the observed behavior. The

simple matching estimator simply replaces the missing observation with the average outcomes for individuals with "similar" values for the covariates. In our case, we choose only one "similar" piece of land (nearest-neighbor matching), where neighborhood distance is determined by the Mahalanobis metric, in which the distance between any two observations with covariates x and z is $d = (x - z)\mathbf{V} - 1\,(x - z)$, where $\mathbf{V}$ is the covariance matrix for X. The Mahalanobis metric is attractive because it takes into account correlation between the various covariates, and scales the coordinate axes. In nearest-neighbor matching, the observation with the lowest distance value is chosen as the match and is used to estimate the pair of potential outcomes.[4] In the absence of exact matching, this estimator can be biased. For this reason, we use the regression function adjustment described by Abadie et al. (2001).

Applied across countries, the treatment effect captures not only the changes in land tenure associated with the different land redistribution strategies, but also all the other changes associated with the transition to a market economy. The land privatization effect is most cleanly identified in Poland, where both private and state-held lands were subject to the same market transition. We can take the abandonment rate on private land as a measure of the abandonment resulting from price liberalization in Poland, while the abandonment rate on previously state-owned land measures the effect of both price changes and changes in tenure status. This comparison gives us the cleanest estimate of the impact of land privatization, as it examines land that is subject to the same macroeconomic policies, but that differs in its tenure status. This structure increases our confidence in the estimations for Poland, which we discuss first, and then use as a comparison between the other countries, from which we can extract only suggestive patterns rather than a causal interpretation.

[4] Our results are robust to matching on more than one neighbor.

Matching Results

The results from the matching analysis are shown in Table 4. The matching variables include elevation, slope, road density, soil quality, and baseline farmland. The table shows comparisons between privately held land in Poland and Polish formerly state-held land (Column 1), Ukrainian land (Column 2), and Slovakia land (Column 3). The estimated treatment effects are the average difference between Polish private land and the comparison group using the matching estimator. Three different outcome variables are used in the analysis: the land distribution prior to 1989, abandonment of farmland, and the farmland per cell calculated in 2000. The "raw difference" is the simple difference between the comparison group and privately held land in Poland. The asterisks on the raw differences indicate significant differences according to a *t*-test.

To begin, it is interesting to note the location of the best matches. Figure 6 zooms in on the Polish sample of the data and codes each cell according to the Mahalanobis measure of distance between it and its closest match, where higher numbers indicate a worse match. The best matches occur in the part of the state land that borders the privately managed area and the part of the privately managed area closest to Ukraine. Examination of the variation in the indices reveals that the main differences are due to deviations in slope and road density.

Beginning with Column (1) in Table 4, we observe that cells located in the privately held area of Poland prior to 1989 have, on average, 41 percentage points more farmland. When this comparison is adjusted for geographical differences using the matching estimator, the difference in farmland distribution across privately and state-held lands in Poland is −10 percentage points. The raw difference in abandonment rates is 0.06 (Column 2, Panel b); significantly more formerly state-owned land in Poland is abandoned than in the private region. However, once this is adjusted for biophysical variation, there is no significant difference in abandonment across the two areas. The matching estimator applied to the final distribution of farmland shows a differ-

TABLE 4
Difference between Private Farmland in Poland and in Other Locations, {*E*[*Y*(*Poland private land*) − *Y*(*Comparison group*)]}

Comparison Group and Outcome Variable	State Land in Poland (1)	Ukraine (2)	Slovakia (3)
a. Farmland Distribution, Pre-1989			
Estimated treatment effect (ATE)	−0.102***	−0.185***	0.010
	(0.011)	(0.010)	(0.015)
Raw difference	0.409***	0.214***	0.326**
	(0.010)	(0.009)	(0.009)
Observations	4,211	9,866	7,050
b. Abandonment			
Estimated treatment effect (ATE)	0.004	0.008	−0.063***
	(0.009)	(0.007)	(0.009)
Raw difference	−0.062***	−0.003	0.048***
	(0.006)	(0.004)	
Observations	3,185	8,001	6,160
c. Farmland Distribution, 2000			
Estimated treatment effect (ATE)	0.013**	−0.004	0.023***
	(0.005)	(0.006)	(0.004)
Raw difference	0.388***	0.200***	0.262***
	(0.009)	(0.009)	(0.008)
Observations	4,211	9,866	7,050

Note: Standard errors in parentheses.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

ence between private and formerly state-controlled regions of 1.3 percentage points[5] (Column 1, Panel b). This quite small difference indicates that in 2000, farmland was distributed almost identically in land of similar biophysical characteristics across the two regions of Poland.

This analysis suggests that the observed difference in farmland abandonment rates between private and state land in Poland is due to differences in geographic characteristics. The results support the hypothesis that state farms were suboptimally located in the first place, and once land allocation restrictions were freed, farmers abandoned unproductive land. Put simply, the vast majority of the abandonment observed in Poland is driven by changes in prices, and it is differences in geography that determine the variation in abandonment rates across Poland. If we assume that private landholders make land use

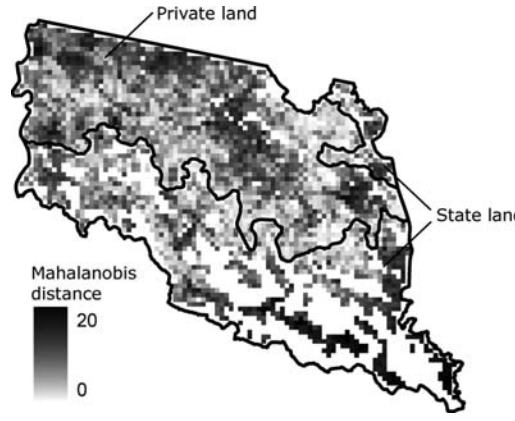

FIGURE 6
Private versus Nonprivate, Poland Only
Source: Authors' calculations.

[5] We also calculate these effects using the best 80% of the matches, that is, discarding the pixels whose best match has a very high Mahalanobis index. This trimming of the outliers results in a significant difference in the distribution of the Mahalanobis index scores, but no significant difference in the point estimates. The trimming also improves the similarity of the covariates. The only covariate that shows a normalized difference greater than one-half of a standard deviation is elevation.

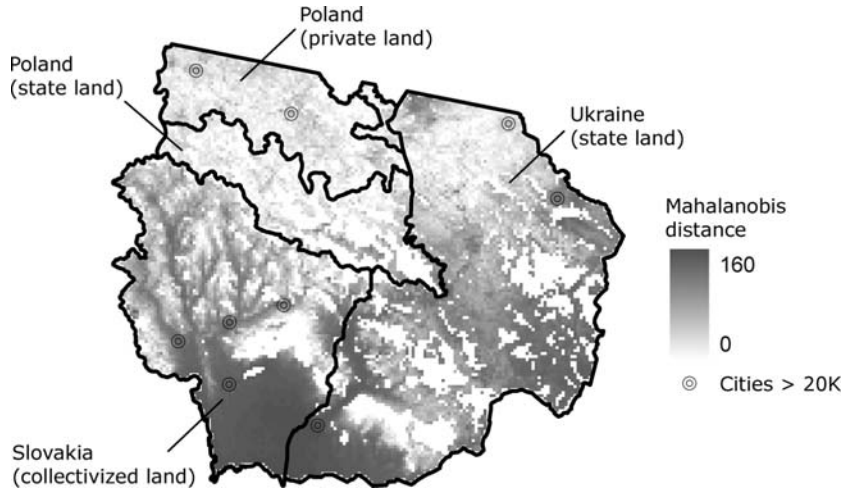

FIGURE 7
Best Matches to Privately Held Land in Poland

Source: Authors' calculations.

choices optimally, we can interpret this result as evidence of the efficiency of the Polish land reform. There are, however, potential confounding factors. For example, if the characteristics of farmers who chose to work on private and state land in Poland were quite different, then the estimator would attribute any variation in outcomes as a result of these characteristics to the treatment effect. This seems unlikely, given the small geographic range over which the data span.

Despite these potential confounding factors, the identification of the effect of biophysical factors versus price liberalization and land tenure institutions is relatively clear in Poland, where both state and private land were subject to similar market transition experiences. One might be tempted to interpret the difference in abandonment rates between private land in Poland and Slovakian or Ukrainian land of similar characteristics as some measure of the impact of different land tenure institutions. To do so directly would be erroneous. These three countries have had very different experiences in their transition to market economies. In particular, the price trends across countries differed considerably over the period studied, even though all three countries ended up with similar levels of price liberalization by 2000 (Figures 2 and 3). In addition, the state has retained much greater control of land rights in Ukraine than in either Slovakia or Poland, and land is not fully transferable. Despite the fact that both tenure status and market experiences are changing simultaneously in these comparisons, it is still revealing to interpret the patterns of land use change within and across these countries.

Figure 7 shows the quality of the matches between private land in Poland and agricultural land in Slovakia and Ukraine. The lighter colors represent the areas where inferences regarding nonbiophysical drivers will be more dependable. The map demonstrates that nearly all of the best matches in Ukraine are located in the northwest corner of the map, while those in Slovakia are scattered in the border region and in the valleys on the western edge of the map.

The top panel of Table 4, Columns (2) and (3) show matched comparisons of baseline farmland across countries. One can think of these comparisons of proportion of farm land across grid cells as a measure of farmland "density." Prior to 1989, farmland density in cells with similar characteristics is approximately the same in Slovakia as in private land in Poland, whereas farmland density in Polish private property is much higher than in Ukraine.

Table 4, Panel b, shows the results of the matching estimator applied to abandonment rates. In Ukraine, the key result is that there is no measured difference in abandonment rates between farmland there and privately held land in Poland; lands with similar biophysical characteristics experienced the same abandonment rates. In the final period, land with similar characteristics in both countries tends toward similar amounts of farmland. The raw differences illustrate the much higher average density in Poland, probably a result of superior biophysical conditions. The results show abandonment rates in private land in Poland to be significantly lower than in Slovakia, especially in comparison to the raw difference in abandonment rates, which indicate that on average over the two regions, there is greater abandonment in Poland than in Slovakia. Also intriguing about the Poland-Slovakia comparison is that the farmland distributions appear to diverge across time: there are greater differences between the farmland distributions in 2000 than there were in 1989.

In order to provide further insight into the land privatization processes, Table 5 presents results of matching estimations using formerly state land in Poland, rather than formerly private land as presented in Table 4. In 1989, farmland was significantly denser on similar land in Ukraine than in state-owned land in Poland, while the opposite was true in Slovakia. Abandonment of state land in Poland was somewhat lower (4 percentage points) in Poland than in Ukraine, and much higher in Slovakia than in Polish state lands. Finally, the differences in farmland distribution of formerly state farms in Poland compared to those on similar land in Ukraine and Slovakia are much smaller in 2000 than in 1989.

That abandonment rates on Ukrainian land are not statistically different from those on similar private land in Poland presents something of a puzzle. Given the large differences in price trends, agricultural yields, and employment in the two countries, one might expect substantially more abandonment on Ukrainian land. The absence of such a difference may support the assertion of some authors (Lerman, Csaki, and Feder 2004) that in fact there was very little practical change in land tenure in Ukraine, as the paper shares granted to former workers were not easily transferable. However, lack of effectiveness of the reform would not necessarily have led farmers to continue farming where it was not profitable, so this cannot be the sole explanation.

The difference in abandonment rates between formerly state lands in Poland and Ukraine is positive; state land in Poland with similar characteristics to that of Ukraine was more likely to be abandoned. This could be interpreted as further tentative support for the hypothesis of the inefficiency of the land reform in Ukraine. It is revealing to refer to Figures 7 and 8 when considering the analysis of abandonment rates. The best matches to private land in Poland are located closest to the large markets in Ukraine, while the best matches to the state land in Poland are located in the more remote and mountainous regions. The propensity toward greater abandonment of Polish state land compared to similar Ukrainian land could also be explained by the persistence of Ukrainian farmers in relatively remote areas. It is worthwhile noting again Bauman et al.'s (2011) result that abandonment rates in this region were much lower than in other regions of Ukraine, and this is also consistent with evidence discussed by Elbakidze and Angelstam (2007). Finally, the suggestion that Ukrainian farmers are more likely to be subsistence oriented is in keeping with analysis on price convergence that shows a relatively slow integration of Ukraine and other countries in the Commonwealth of Independent States into the global economy (Solakoglu and Civan 2006).

The large differences in the geographically neutral comparisons of Slovakian farmland abandonment with Polish land in both tenure-constant and tenure-reformed areas indicate important impacts of either or both relative prices and land reform. The statistics in Table 2 demonstrate that off-farm employment opportunities in Slovakia were superior to those of Poland. This is likely to correspond to a lower ratio of output-to-input prices in Slovakia than in Poland. Prior to the transition, Slovakia's employment was the least dependent upon agriculture out of the three countries, despite having considerably better soils than in the other two countries, at least in the

TABLE 5
Difference between Previously State-Owned Farmland in Poland and in Other Locations, {*E*[*Y*(*Poland formerly state land*) − *Y*(*Comparison group*)]}

Comparison Group and Outcome Variable	Ukraine (1)	Slovakia (2)
a. Farmland Distribution, Pre-1989		
Estimated treatment effect (ATE)	−0.141***	0.057***
	(0.007)	(0.014)
Raw difference	−0.195***	−0.326***
	(0.008)	(0.009)
Observations	10,125	7,309
b. Farmland Abandonment		
Estimated treatment effect (ATE)	0.041***	−0.179***
	(0.012)	(0.014)
Raw difference	0.060***	−0.048***
	(0.005)	(.007)
Observations	7,468	5,627
c. Farmland Distribution, 2000		
Estimated treatment effect (ATE)	−0.024***	0.035**
	(0.006)	(0.015)
Raw difference	−0.188***	−0.261***
	(0.008)	(0.008)
Observations	10,125	7,309

Note: Standard errors in parentheses.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

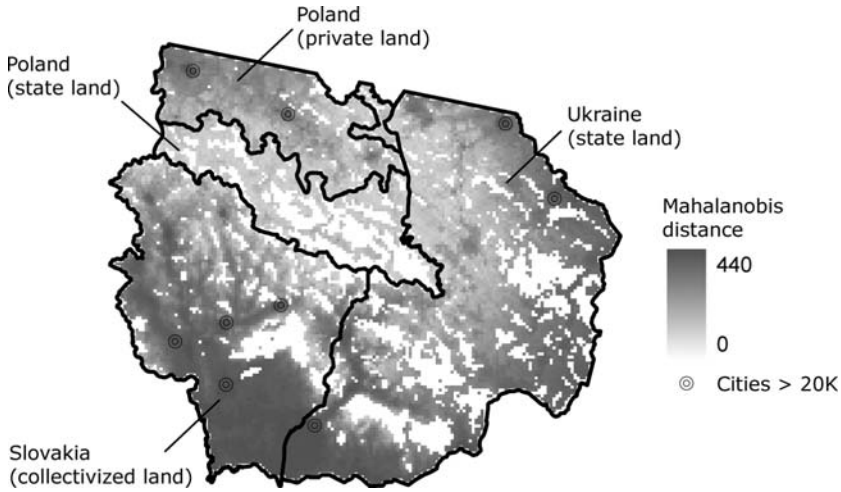

FIGURE 8
Best Matches to Previously State-Held Land in Poland

Source: Authors' calculations.

regions under comparison here. According to *World Development Indicators* (World Bank 2011), by 2000, agricultural employment had dropped 45% in Slovakia and 26% in Poland, while it had increased by nearly 23% in Ukraine. Therefore, differences in labor costs and agricultural labor demand across countries must be driving at least part of the results.

The second possible effect involves the institutional structure of the decollectivization process. Slovakia's land reform involved the restitution of land to former owners, a process that required locating these owners. Because they lived in cities or had no farming experience, former owners, or their heirs, were often not interested in farming (DLG 2005; Müller et al. 2009; Csaki et al. 2003). Where former owners could be found, they often leased their land back to large agricultural enterprises. One might argue that, in contrast, Poland's auction process immediately put land in the hands of owners who might use it productively. Slovakia and Poland experienced similar trends in agricultural yields over the transition period, with an average decrease in yield indices of 2.5 and 1.5 for Poland and Slovakia, respectively, in the first five years, and average increases of 2.5 and 3.0 in years 5–10 (Rozelle and Swinnen 2004). The pattern of more precipitous declines in productivity in Slovakia followed by greater increases in productivity in Poland suggests that the difficulty of putting land in the hands of former owners in Slovakia may explain a part of its much higher agricultural land abandonment rates.

VII. CONCLUSIONS

To conclude, we return to our overarching question: how did market liberalization, land tenure institutions, and geography influence farmland abandonment in Eastern Europe? In the context of Poland, it is clear that land privatization did not drive farmland abandonment: abandonment among land without any change in tenure status averaged 12.7% per 1 km^2 cell. Furthermore, the observed difference in abandonment between land without any tenure change and newly privatized land can be entirely explained by differences in geography. In Poland, differences in land abandonment across private and formerly state-held land are determined by the fact that much former state land was located in places that were not productive enough to be profitable in a market economy. Geographically similar land in Poland shows identical abandonment rates.

In Slovakia, if one were to make the assumption that price fluctuations were equivalent to those in Poland, one might claim that Slovakia's decollectivization process, and the attendant difficulties of locating absentee owners, resulted in additional land abandonment. However, aggregate employment and income statistics suggest that at least part of this difference must be attributed to better nonfarm employment opportunities in Slovakia.

Ukraine presents the puzzle of having clearly different prices and productivity than Poland, but very similar abandonment rates. Two countervailing forces may explain this result. Low agricultural productivity and dramatic decreases in input subsidies might lead to higher abandonment rates, while limited off-farm opportunities may keep people on the land, leading to greater dependence upon subsistence agriculture and thereby lower abandonment. The comparison of Ukrainian land to (initially) private land in Poland reveals similar abandonment rates, possibly because the land that is most comparable is found in markets that are well connected. The significantly greater abandonment rates in (mountainous) formerly state land in Poland, relative to similar Ukrainian land, provides suggestive evidence for increased dependence upon subsistence agriculture in more remote areas.

More broadly, our analysis submits that both geography and institutions have played important roles in determining land use change in the Carpathians region. While price liberalization is clearly responsible for overall high abandonment rates, biophysical considerations tend to have been more of a driving force in the variation in these rates across the region. In the case of Poland, one might even propose that the biophysical differences between the regions drove the initial choices of the type of tenure system that was developed in the Soviet period.

We can tentatively compare the three types of privatization represented in this data set. The auctioning system put into place in Poland appears to put land into its most productive uses more quickly than the restitution or share distribution systems in Ukraine and Slovakia. It also seems that, more than the change in land tenure regimes, changes in prices have

driven abandonment in the region, particularly in Poland and Slovakia. In Ukraine, farmers have been less responsive to market prices because their productive systems tend toward subsistence rather than market orientation. In all three countries, farmland distributions on biophysically similar land are converging.

Finally, the land abandonment in this region might be considered environmentally beneficial in that afforestation creates greater reservoirs for carbon sequestration—a global benefit (Kuemmerle et al. 2011). However, large-scale farmland abandonment in the region might also be a threat to the "amenity" of the traditional village landscape, which is valued locally, and to the biodiversity associated with cultural landscapes. With this in mind, the relatively low level of abandonment in the Ukrainian section of the study region may be more beneficial than it first appears, given its potential association with landscape preservation. Understanding abandonment is crucial to determining how social and environmental costs of production vary across space, and how the reconversion of this land back into agriculture might affect these tradeoffs.

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