Markets, Privatization and Resource Management: Understanding land use decisions after institutional change in European Russia

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A. INTRODUCTION

I. Overview

The purpose of this dissertation is to analyze how institutional change has affected land use in Russia. A fundamental challenge in natural resource management is designing appropriate governance and use patterns to obtain the desired level of economic and ecological outcomes. When the Soviet Union collapsed in 1991, Russia had to decide how land should be managed. This included deciding about ownership and use patterns as well as tradeoffs between resource extraction and conservation goals. At the national level Russia embraced capitalism. Reflecting this shift toward a market-based economy, Russia privatized its timber industry and began allocating use rights through auctions. Russia chose to privatize ownership of agricultural land. For the production of both timber and agriculture Russia ended Soviet-era subsidy programs to allow the market to determine optimal supply and demand.

Almost twenty years after the collapse of the Soviet Union social scientists have written extensively about the transition process to a market-based economy (a small sample include: Hellman 1998; Shleifer and Treisman 2000; Herrera 2001; Frye 200l; Roland 2002; Appel 2004; Hedlund 2005; Letiche 2007; Brancato 2009). One of the main lessons to emerge from this literature is that shifting governance and property rights structures amidst weak institutions has at best resulted in a slower than expected transition and at worst resulted in negative social and economic outcomes for Russia (Hellman 1998; Volkov 1999; Way 2002; Svejnar 2002; Shleifer and Treisman 2005; Ledeneva 2006). As the formal institutions broke down in Russia, informal systems such as the barter economy emerged (Gaddy and Ickes 2002) and corruption and organized crime became serious obstacles to reform (Volkov 1999; Karklins 2005; Ledeneva 2006). Resource management was impacted by the turmoil and uncertainty that followed the Soviet Union's collapse and the outcomes have been less than optimal: forest harvesting rates declined, investments in sustainable forest management declined, and farm productivity declined (IIASA; Lerman et al. 2004; Ioffe et al. 2004; Eikeland et al. 2004; Olsson 2008; Torniainen 2009; Lerman 2009). These dismal outcomes have been linked to the same challenges that plagued the overall transition process: weak formal institutions, incomplete reform, strong informal rules and norms, and corruption.

The privatization of timber use rights in forestry and ownership of agricultural land in Russia and the subsequent economic and ecological outcomes provide a natural experiment to study the impacts of market-based resource management under weak institutions. In particular, it provides an opportunity to evaluate how external factors affected the transition from an open access system of resource management to a market-based system and the implications for land use. In this dissertation project I will have panel data on timber harvesting and agricultural land abandonment at both meso- and micro-scales within European Russia. I will use econometric models to understand the relationship between the transition to market-based institutions and observed harvesting rates and land abandonment decisions. These results will be used to forecast changes to timber harvesting and land abandonment under alternative institutional and incentive arrangements.

In **Chapter 1** I will analyze spatial and temporal trends in timber harvesting in the temperate and mixed forested regions of European Russia across at least ten years. I am specifically interested in describing how privatization instruments – privatization of firms and leasing arrangements – affected harvesting rates after transition to a market-based system. The motivating research question will be: ***how did privatization affect harvesting rates in post-Soviet Russia?*** To fully understand how privatization affected timber harvesting I will analyze the determinants of the volume of timber sold at competitive auctions and changes in the number and output of private timber firms. Chapter 1 will focus on the meso-scale, using regional-level statistics collected annually from Russia's National Forest Service and National Statistical Service. The expected outcomes of this chapter include: a descriptive understanding of how timber firms changed in number and size after privatization and their interactions with the state forest sector; a descriptive understanding of the evolution of competitive auctions and timber prices over time in the study region; and estimation of how timber firms and competitive auctions impacted the volume of timber harvested. This research will provide important knowledge about the interactions between actors and use of market-based instruments in the forest sector in post-Soviet Russia, leading to causal hypotheses about how these interactions affected the volume of timber harvested.

In **Chapter 2** I will focus on the same regions in European Russia and couple remote sensing analysis with socioeconomic modeling to estimate the determinants of timber harvesting rates. This chapter will draw on findings from Chapter 1 about privatization impacts and other determinants of timber harvesting at the regional level and will also bring in information at the district level; the study period will be 1990 to 2005. This analysis will allow intra-regional variations to be estimated and will provide more accurate measurement of forest harvesting following the collapse of the Soviet Union since it does not rely on national statistics. The remote sensing measure of forest harvesting will be compared to national statistics, resulting in an approximate measure of reported and unreported harvesting levels. The motivating research questions for this chapter are: ***1) what determined timber harvesting rates in post-Soviet Russia?*** ; ***2) what factors are***

associated with unreported logging?; and 3) how would changes to forest institutions and incentives affect future harvesting? The outcomes of this chapter will include: an econometric model of the determinants of timber harvesting since independence; forecasts of timber harvesting under business as usual and alternative institutional and incentive arrangements; and a description of the factors that led to more illegal logging. This research will provide an overview of changes to timber harvesting in Russia since independence and inform future management options.

In **Chapter 3** I will focus on one region and conduct a micro-level analysis of land-use change since transition that includes timber harvesting and land abandonment. This chapter will shift focus from the economic outcome of timber harvesting to evaluate current and future conservation implications of land management. To inform conservation science, spatially-explicit information on land-use change is needed. In this chapter I will model timber harvesting and land abandonment decisions at the parcel level and use these estimates in simulations of future landscape patterns. These simulated landscape patterns will be used as inputs into habitat suitability models for moose, wild boar, and wolf. This knowledge will be used to assess the conservation impacts of land management under business as usual and alternative scenarios. The motivating research question for this chapter is: ***what are the implications of current land management for wildlife conservation?*** The expected outcomes of this chapter include: development of micro-level econometric models for land abandonment and timber harvesting decisions; simulations of landscape patterns under current land management and alternative scenarios; and assessment of the impacts of land management on wildlife conservation. This research will provide one of the first empirical assessments of the impacts of institutional and land-use change on biodiversity in Russia.

In summary, my dissertation project focuses on how transition to a market-based system of resource management impacted land use in European Russia. It will identify how privatization and other market-based tools (e.g., auctions) impacted resource outcomes and characterize how external factors such as weak institutions and informal rules affected the efficacy of these new market-based processes. Within the study region, these results will be used to evaluate the implications for future timber management and wildlife conservation. Additionally, understanding how external factors impacted transition to a market-based resource management system can provide important lessons outside of Russia given the burgeoning interest in market-based instruments for managing resource stocks and environmental services (Freeman and Kolstad 2007; Engel et al. 2008).

Before proceeding, it is also important to clarify what I will not do in this dissertation. First, I will not focus on the theory behind markets and privatization for resource management, and thus whether the policies Russia put into place were the "right" ones. In this research I take these institutions as given. Second, while I am interested in the hurdles Russia faced in implementing market-based policies, I will not focus on explaining why these hurdles developed. A number of papers have catalogued the institutional constraints within forestry and agriculture and the impact of weak institutions on the reform of these sectors (in forestry: IIASA website; Olsson 2008; Torniainen 2009; in agriculture: Lerman et al. 2004; Ioffe et al. 2004; Lerman 2009). Finally, my intention is not to evaluate the effectiveness or impact of privatization or other market policies on land use outcomes per se; creating a counterfactual for these policies is nearly impossible given the substantial number of changes occurring within Russia during the transition period and the fact that resource policies were implemented uniformly across space.

The rest of this proposal proceeds as follows. In the remainder of Part A, I articulate my overarching research framework, describe the study area, and provide some background on forest management and agriculture in post-Soviet Russia. In Part B, I describe the three chapters proposed above in more detail. In Part C, I summarize the expected outcomes and overall significance of my dissertation project. Following Part C is an appendix with a detailed timeline for this dissertation project and the conferences and journals that I will target.

II. Theoretical Framework

This dissertation project draws predominately on two fields: institutional theory and land change science. The overarching framework is institutional theory, also referred to as institutional analysis. Institutions in this framework mean the rules, norms and conventions that guide human action (North 1990). Institutional theory is a broad discipline that encompasses many questions: how institutions evolve, the impacts of institutions, and the influence of external factors on how institutions work (Ostrom 2005). Institutional analysis is an interdisciplinary science, but questions of institutional change are mostly addressed within the fields of political science and economics. Institutional analysis assumes that institutions and politics play an explicit role in economic decision-making and in shaping preferences. Fundamentally, it envisions the economy as a place where the state, institutions and the market are interrelated.

In this research, I am interested in institutional theory primarily because Russia underwent an unprecedented institutional change after the collapse of the Soviet Union. The most fundamental of these new institutions was the development of a market-based economy where prices would be determined by supply and demand. A market is nothing but a system of rules about exchange: who can sell what to whom and at what price. Assigning property rights is necessary to achieve the economically efficient equilibrium within a competitive market. Institutional change is a key instrument used throughout resource management. Regulatory instruments and market-based instruments all change what an actor can and cannot do with respect to a particular environmental resource and are thus changes to the "rules of the game" for resource management. The institutions implemented in Russia – creation of a market-based economy, privatization and allocating use rights – are all examples of the broader suite of market-based instruments used in resource management that rely on setting prices or quantities. The transition to a market-based economy in Russia was aimed at creating a competitive market for resources based on price signals while the creation of property rights was meant to facilitate the economically efficient quantity of resource use.

Since the outcomes I am interested in assessing in this dissertation are related to land use, the other field that I draw on is land change science. Land change science is also interdisciplinary in nature and draws on remote sensing, resource economics, and landscape ecology, to name just a few disciplines (Turner et al. 2007). A key aspect of land change science is that it accounts for the spatial relationship and patterns between land and decision processes. Resource economists contribute to land change science by building models that seek to explain human-driven land-use changes. The pairing of remote sensing data with econometric models creates a rich opportunity for research on land-use change. Chapters 2 and 3 draw most explicitly on the theory and methods of land change science by combining remote sensing analysis with econometric models of land-use decisions.

Modeling the drivers of land-use change is complicated by the fact that there are both proximate factors of change – e.g., individual actions – and underlying factors of change – e.g., macroeconomic policies and national institutions (Lambin et al. 2001). One of the classic papers categorizing the types of land-use change drivers is Angelsen and Kaimowitz's 1999 meta-analysis of 140 studies of deforestation. These authors make an explicit distinction between underlying causes (the macroeconomic variables and policy instruments), immediate causes (the institutions, infrastructure, markets, and technology) and sources of deforestation (the agents of deforestation). Recently, land change science has started to focus on these larger institutional and macroeconomic processes that influence an individual's land-use decisions and have challenged researchers to include these exogenous factors into their modeling framework. Lambin et al. (2001) specifically discuss the need to focus beyond the individual decision-maker, writing:

> "…individual and social responses follow from changing economic conditions, mediated by institutional factors. Opportunities and constraints for new land uses are created by markets and policies…" (Lambin et al. 2001, p.266)

Lambin et al. (2001) go on to conclude:

> "These pathways indicate that land-use policies and projections of the future role of land-use change in Earth System dynamics must not only capture the complex socio-economic and biophysical drivers of land-use change but also account for the specific human-environment conditions under which the drivers of change operate." (Lambin et al. 2001, p.267)

By coupling land change science with institutional analysis, this dissertation project explicitly takes into account the impacts of underlying causes, immediate causes and sources of land-use change in post-Soviet Russia.

III. Study Area and Background

Study Area

Russia contains 20 percent of the world's forests or close to 809 million hectares (ha) of forestland in 2005 (FAO 2005). Thus, Russia is an important supplier of timber and non-timber forest products for the world. This research project focuses on the temperate and mixed forests of European Russia (Figure 1), where temperate coniferous, temperate broadleaf and mixed forests dominate the landscape. In the extreme north of the study area are coniferous forests. As one moves south the mixed forests begin and while coniferous species such as spruce (*Picea abies*) and pine (*Pinus sylvestris*) are still found, deciduous species appear. The major deciduous species include lime (*Tilia cordata*), oak (*Quercus robur*) and birch (*Betula pendula*) in the eastern part of the study area, and beech (*Fagus sylvatica*) and hornbeam (*Carpinus betulus*) in the western part of the study area. Closer to the Ural Mountains, lime-dominated forests are common (Serebryanny 2002; Hytterborn et al., 2005).

Figure 1. Temperate and Mixed Forests

Politically, Russia is a federation and was divided into 83 federal subjects as of 2010. While the subjects have equal representation in the federal government their degree of autonomy varies according to status. The most common types of federal subjects are oblasts – of which there are 46 – and republics – of which there are 28. Oblasts have a federally appointed governor and a locally elected legislature. Republics have greater autonomy and elect their own president, parliament and constitution. These federal subjects are administratively organized into eight federal districts. Within federal subjects political units are further divided into municipal districts, which have their own local council with elected representatives. My study area (Figure 1) covers three federal districts, 27 federal subjects (referred to as regions for the remainder of this proposal) and 372 municipal districts (referred to as districts for the remainder of this proposal). It covers the two largest cities in Russia – Moscow and St. Petersburg. Twenty-one of the regions are oblasts and six are republics.

Background

<u>Forest Management</u>

The temperate forests of European Russia are under at least as much pressure from industrial logging as the boreal forests in Siberia. This is a direct result of the accessibility to timber in European Russia as compared to Siberia. Historically, European Russia has accounted for about 60 percent of all timber harvesting even though it contains only 25 percent of Russia's timber resource (Serebryanny and Zamotaev 2002). At the end of World War II timber harvesting increased steadily from about 2 million cubic meters (m^3) per year, peaking at around 4 million m^3 in the late 1950s (Figure 2). Timber harvesting declined in the late 1950s and then again in the mid-1970s. While declines suggest a steady depletion of the resource stock, the collapse of the Soviet Union led to an unprecedented downturn around 1989. According to national statistics, in 2003, regions in this study contained approximately 9 billion m^3 of growing stock over about 60 million ha of forestland.

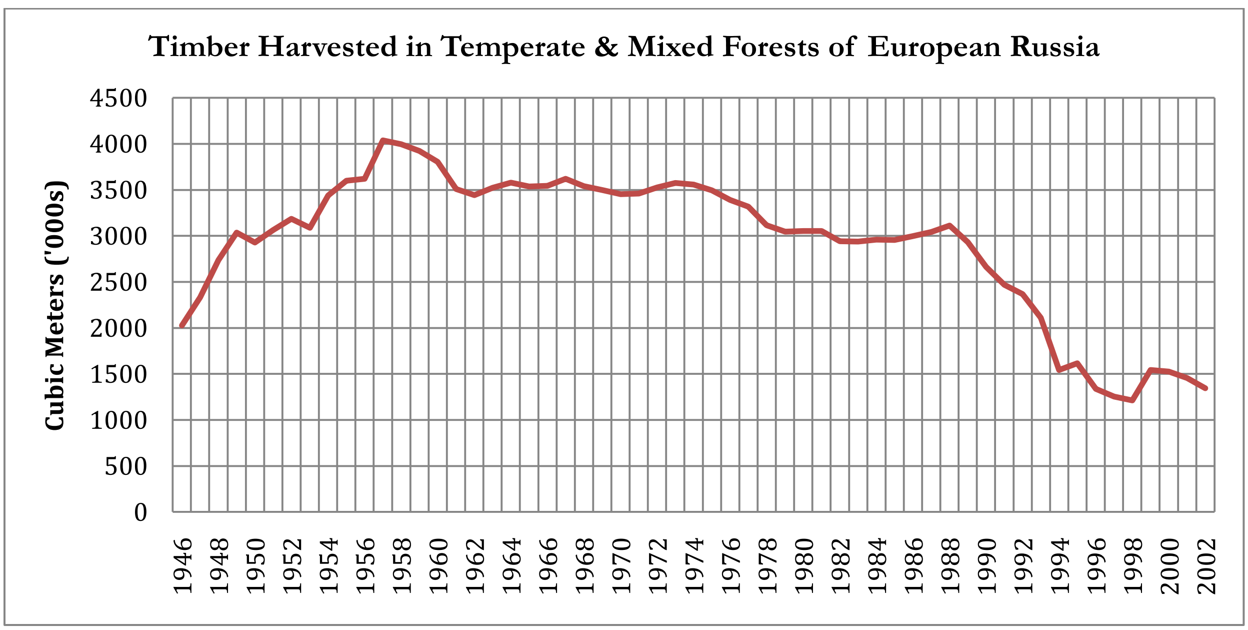

Figure 2. Timber harvested in the study area between 1946 and 2002

Despite the large amounts of timber harvested during the Soviet period, timber utilization under the command and control economy was economically inefficient due to too many authorities with unclear roles, defective administration and poor management, lack of silviculture, waste of raw material, lack of skilled labor and inefficient forest industry (Nilsson et al. 1992). From an economic perspective, under central planning the balance between benefits and costs were skewed, leading workers to cut a larger quantity of timber than necessary. The workers would then extract the most valuable species and discard the rest of the timber (Brown and Wong 1993). In addition to overharvesting at local levels, Soviet era policies led to neglect of forest regeneration and silvicultural activities in order to reduce costs (Torniainen 2009). The result was a rapid decrease in coniferous forests in Russia and an increase in deciduous forests; however, most local industries are poorly equipped for processing hardwood species (Yaroshenko, personal communication).

The first signs of change to Russia's political and economic structure, and thus forest management, began in 1985. This was the year that Soviet leader Mikhail Gorbachev introduced policies to restructure the Soviet economy and bring political openness. A series of events transcended, which ultimately led to the official collapse of the Soviet Union in 1991 and the creation of fifteen independent republics. Quickly after this collapse, the Russian Federation embraced market-oriented policies. The three main policies implemented for this conversion to capitalism were: 1) liberalization, 2) stabilization, and 3) privatization. By the mid-1990s, Russia had sunk into economic depression which culminated during the 1998 Russian financial crisis. Policy reforms, influxes of cash from donors, and rising oil prices in 1999 led to recovery and a general trend in economic growth following the crisis. On the political front, Russia adopted a new constitution in 1993 that established Russia as a democratic federal-based nation with state power divided between the executive, legislative and judiciary branches. This period marked an increase in power for Russia's regions, particularly during the Yeltsin era (1991-1999).

Russia's transition to new political and economic structures affected forestry both directly and indirectly. Directly, significant changes were made to forest governance and utilization: management was decentralized and use rights were privatized. Indirectly, the massive socioeconomic changes occurring within Russia reduced local demand for forest products, while at the same time timber needs within Russia were increasingly served by Western competitors (Backman 1995, 1996). The combination of shifting timber demands, new international markets, new forms of governance, and privatization led to turmoil in the forest industry. This was further confounded by several substantial changes to forestry legislation in post-Soviet Russia and an overall dismal economic climate for newly privatized timber industries (Eikeland et al. 2004).

The first official forestry laws for independent Russia were the 1993 Principles of Forest Legislation. This legislation split forest management and industrial activities. Forest management – including silvicultural investments and allocation of use rights – remained the realm of the state, but many of the decision-making powers were decentralized to district and regional-level administrators (Krott 2000; Eikeland et al. 2004). Forest industry – including timber harvesting and processing – became the responsibility of private enterprises. The majority of these private timber enterprises were the remnants of the state-controlled Soviet-era enterprises; however, as liberalization took effect Russian forest corporations, Russian businessmen and oligarchs, and foreign investors began to move in and establish new forest enterprises. To allocate use rights to these private enterprises competitive auctions were to be used. One change that did not occur to forest management was transfer of ownership rights of forests. Unlike in several other former Soviet countries, Russia chose to maintain state ownership of forestland.

From 1993 until 1997, the majority of forest management responsibilities were devolved to local forest management units (FMU). These FMU operate on a geographical scale roughly equivalent to Russian municipal districts. Forest management during this period has been characterized as corrupt and inefficient (Eikeland et al. 2004). There are two factors that contributed to these results. One factor was that FMU lacked the technical skills and training to take on these new responsibilities (Krott 2000; Torniainen et al. 2006). The other factor was that the 1993 legislation took away the primary source of funding for FMU: forest harvesting. Without supplemental budgetary resources coming from Moscow, local FMU had to rely on (illegal) harvesting and high taxes and illegal fees on forest leases to generate revenue (Eikeland et al. 2004).

New forest enterprises also had many hurdles to overcome as Russia transitioned to a market-based economy. Many of the former state enterprises failed once federal financing ended. A lack of capacity hindered former state employees in taking on their new roles of procuring markets for products and finding investment capital. Former state enterprises and many of the new actors that moved into the timber industry were adversely affected by the high taxes and fees set by the local FMU to offset their budget deficits (Yaroshenko, personal communication). For example, high auction prices in Murmansk oblast in Northwestern Russia contributed to declining rates of timber harvesting and the bankruptcy of many timber enterprises (Eikeland and Riabova 2002). During this period of uncertainty many private timber enterprises reverted to a barter system of exchange. This phenomenon was not unique to the forest sector as a "virtual economy" developed throughout Russia after the collapse of the Soviet Union (Gaddy and Ickes 2002).

Use rights to forests, and how they were allocated after privatization, are particularly important for my research questions. Starting in 1993 official policy was that forestland could be allocated for four purposes: 1) timber concessions for up to 49 years; 2) short-term timber leases for less than five years; 3) silvicultural leases for forest maintenance activities; and 4) personal use leases for activities such as fuelwood harvesting (Yaroshenko, personal communication). In this research project I am only interested in the first two user rights. Timber concessions were allocated using auctions while short-term leases were allocated on a non-competitive basis. In both cases, the responsibilities of the forest user only included harvesting, not maintenance or reforestation. The 2007 Forest Code revised these responsibilities, with maintenance and reforestation becoming the obligation of the leaseholder. While concessions and short-term leases could be allocated as early as 1993, use of these mechanisms was slow to start. Sixty-eight percent of all economically accessible forests in Russia were leased (non-competitive and competitive) as of 2006 (Torniainen et al. 2007). Access to timber rights was influenced by the interplay of political and economic actors in Russia, with local and regional forest service employees having the authority to grant use rights (Torniainen 2009).

Toward the later part of the 1990s more favorable shifts occurred in Russian forestry. In 1997, a new Forest Code was issued. The main change was that decision-making authority was taken away from local FMU and bestowed to regional forest managers. This shift in authority helped reconcile the problem of high taxes and auction prices by taking the power away from local actors. However, it failed to address the perverse incentives faced by local FMU to cut timber to provide income (Torniainen et al. 2006). The financial crisis that hit Russia in 1998 also led to a turning point for timber enterprises. The ability of timber enterprises to export increased considerably after Russia deregulated its currency following this financial crisis. The central government recentralized forest authority in 2000. In 2007 Russia released its latest version of the Forest Code. This new Forest Code once again decentralized decision-making powers to the regional level and makes considerable adjustments to the responsibilities of timber enterprises. Torniainen et al. (2009) provides an in-depth overview of the changes in this round of the Forest Code. Thus, forest decision-making authority shifted several times between local, regional and federal forest sector employees after 1993 (Table 1).

Within the timber industry there has been a significant concentration in enterprise ownership and production output; e.g., in the case of pulp and paper mills about a dozen mills account for almost 75 percent of total output (Kortelainen and Kotilainen 2003; Torniainen et al. 2006). Nationally, forest output remains low, with about 23 percent of annual allowable cut utilized as of 2003 and contribution to national gross domestic product only about 3 percent (Torniainen et al. 2006). However, the forestry sector has been regaining speed since 2000 with political stabilization fostering increased foreign investments in mills (Williams and Kinard 2003). One potential hindrance to this growth was the change in Russian roundwood export taxes in 2009. Turner et al. (2008) evaluated this change prospectively and found that the proposed increase would lower harvest rates by around 19 percent and exports by about 50 percent by 2020; Russian forest stock would benefit from these changes, with about 0.3 percent growth by 2020.

Table 1. Russian Forest Authority and Management

		Main principles of forest legislation, 1978	Main principles of forest legislation, 1993	Forest Code, 1997	Federal Law no. 122, 2004	Forest Code, 2007
Federal level	Ownership	X	X	X	X	X
	Law-drafting	X	X	X	X	X
	Decision-making	X			X	
	Control	X	X	X	X	X
Regional level	Ownership					
	Law-drafting			X		
	Decision-making			X		X
	Control					
Local level	Ownership					
	Law-drafting					
	Decision-making		X			
	Control					

Source: Torniainen et al. (2006), author updated for 2007 Forest Code

Agricultural Land Management

During the Soviet era there was a massive expansion in farmland in Russia: from 52 million ha in 1921 to about 127 million ha in 1978 (Ioffe and Nefedova 2004). During the Soviet period the state owned all land and most farmland was cultivated collectively in state farms. These farms were large – thousands of hectares – and employed hundreds of workers. The production targets for these farms were determined by the state and many farms were heavily subsidized. The inefficiencies of this farming system are well known: supply and demand was not determined by market signals, farms had soft budget constraints, and there were high transaction costs given the size of farms and number of employees (Lerman et al. 2004). In addition to collective farms, rural households typically owned and farmed subsistence-based plots of less than one hectare.

Russia adopted an amendment in the late 1980s to privatize agricultural land; however, it was not until 1991 that wide-scale distributions of land began. Paper shares were given to all former collective farm employees and entitled them to a parcel of land. The method of converting paper shares to physical shares proved cumbersome and costly, and has resulted in more than 50 percent of collective land remaining unclaimed (Shagaida 2005; Lindner 2007; Lerman and Shagaida 2007). Land that is not claimed often remains in joint use by former collective farms.

Today three types of farms exist in Russia: corporate farms which closely resemble former collective farms, individual peasant farms or private farms, and subsistence-based household plots. The managers of many of the Soviet era state farms became the managers of the new corporate farms. These farms tend to be greater than 1,000 hectares and lease the majority of their land from private owners. Corporate farms employ hundreds of workers but typically employ fewer workers than in Soviet times. In general they have benefited from access to credit and markets and are located in the more productive agricultural regions of Russia (Ryloko and Jolly 2005). The new type of farming that evolved after independence was peasant farms. These farms are on average 100 hectares and are owned by individuals that claimed their land shares from the government. They tend to rely on family labor and represent only a small portion of land in Russia (Lerman et al. 2004). Subsistence-based plots are a carry-over from Soviet times; they are typically less than one hectare. The overall farming structure is in many ways similar to that under Soviet rule: a large proportion of small farms control a small proportion of land and a small proportion of large farms control a large proportion of land (Lerman et al. 2004; Uzun 2005).

Even before the collapse of the Soviet Union the area of cropland in Russia had begun to decline. This probably reflects the massive expansion that took place under the Soviet Union and the fact that almost four-fifths of this land was in marginal productivity zones of the country (Ioffe and Nefedova 2004). In addition to marginal lands being abandoned, a number of other contributing factors have led to the increased abandonment since transition: new economic opportunities and rural depopulation, reductions in farm subsidies, and credit and market constraints. Even before the collapse in 1991 a rural exodus had begun in Russia. With emerging economic opportunities after the collapse, depopulation of rural areas continued and was a leading cause of land abandonment (Ioffe et al. 2004; Lerman 2009). Following independence, Russia ended Soviet era agricultural subsidies to farms and in general, has provided few investments into agriculture for the country. With the advent of privatization this has meant that many farms that cannot cover their costs have gone bankrupt (Ioffe et al. 2004). In addition, credit constraints and markets have impacted farm productivity. Credit constraints have mainly affected the production of peasant farms, as most banks will not lend to small businesses (Uzun 2005). Constraints in developing a land market have also limited the efficiency of agricultural land use in Russia. For several years there was a moratorium on selling land. While this moratorium has ended, mechanisms to lease land are not well developed. Recent studies find that a demand for land exists but that transaction costs of procuring land are prohibitive (Shagaida 2005; Sazonov and Sazonova 2005).

B. CHAPTERS

B.1. Chapter 1: The impacts of privatization on the Russian forest sector

Research Question: How did privatization affect harvesting rates in post-Soviet Russia?

I. Overview

Following the collapse of the Soviet Union in 1991, the Soviet-era forestry system was split into two entities: a state forest sector responsible for silviculture and administration and a privatized timber industry responsible for felling and production. Throughout Russia privatization of state-owned enterprises was a response to the perceived inefficiencies of the Soviet regime and was expected to improve managerial incentives and encourage firm restructuring (Nysten-Haarala 2001; Brown et al. 2009). Ownership of natural resources were excluded from privatization but other rights to forests, specifically the right to lease forests for harvesting, were regulated in 1992 (Nysten-Haarala 2001). Leasing agreements between the state forest sector and private timber enterprises were meant to facilitate economically efficient timber harvesting (Papilla 1999). Over the past twenty years forest harvesting rates and investments in forest health and regeneration have declined while illegal logging has increased (Carlsson et al. 2000; Serebryanny and Zamotaev 2002; Eikeland et al. 2004; Archard et al. 2006). In this chapter I will analyze how privatization of timber use rights – specifically the creation of private timber firms and lease contracts – affected timber harvesting rates following independence. In addition, I will characterize the use of competitive auctions and the evolution of timber firms across regions. Results from this work will provide descriptive knowledge about how the implementation of privatization policies affected timber harvesting in Russia, leading to testable hypotheses about what caused the decline in timber harvesting after the collapse of the Soviet Union.

This chapter will focus on 27 regions within the temperate and mixed forest zones of European Russia. The temperate and mixed forests account for around 25 percent of timber stock but produce nearly 60 percent of all timber harvests (Serebryanny and Zamotaev 2002). Given their accessibility and proximity to human populations, how privatization worked in these regions serves as an important baseline for sustainable forestry throughout Russia and provides lessons for other countries adopting market-based resource policies. Timber harvesting rates are the primary outcome of interest since they measure economic productivity in the forest sector after institutional change. In a well-functioning market system, private timber firms and the volume of timber sold in competitive auctions should positively impact the volume of timber harvested. I will use a combination of descriptive statistics and regression models to analyze whether this positive relationship between timber firms, auction rates and timber harvesting holds in post-Soviet Russia. Similar methods will be used to explore the relationship between forest resources, private timber firms, and the use of competitive auctions. Data for this paper will come from two main sources: the Russian National Forest Statistical Database (Goskomstat Rossii) and the Federal Agency of Forestry of Russia. Currently, I have data from 1993 to 2002 but I will try to extend the study period to 2005[1].

II. Background

The first official forestry laws for independent Russia were the 1993 Principles of Forest Legislation that split forest management and production activities. Management authority and power was decentralized to local administrators (Krott 2000; Eikeland et al. 2004). Since 1993, two Forest Codes have been issued – the 1997 and 2007 codes – and other legislation that have changed the power-sharing structure considerably. The table taken from Torniainen et al. (2006) and updated for the 2007 Forest Code summarizes the changes to forest authority since transition (Section A, Table 1). The most notable changes were the shift in power from local to regional administrators in the 1997 Forest Code and the complete recentralization of power in 2004. Despite these legislative shifts, experts suggest that very few substantive changes occurred in the types of forest management decisions that were made by government forestry workers (Yaroshenko 2009; Laestadius 2009). Similar results were found by the "Institutions and the Emergence of Markets – Transition in the Russian Forest Sector" assessment carried out by the International Institute for Applied Systems Analysis (IIASA). Their reports and publications summarize the reasons behind the breakdown

[1] Extending the time period would make the results more relevant to current policy analysis and would be beneficial for applications in Chapter 2.

within the forest sector, including: unclear roles and responsibilities under the new legislation; little enforcement of formal rules; and few supporting mechanisms for implementation of the new policies. They conclude that the breakdown in formal rules led forest personnel to revert back to the strong informal norms from the Soviet era (Olsson 2008; Torniainen 2009).

Russia privatized state logging companies, pulp and paper mills, and sawmills in 1993. To allocate timber to private enterprises the government used leasing mechanisms (Jacobsen 1999). Former employees of the Soviet enterprises took over most of the newly privatized timber entities. However, once the federal government stopped financing these institutions and price liberalization was put into place, many of these industries went bankrupt or moved into the "virtual economy" (Gaddy and Ickes 2002). Within the virtual economy enterprises bartered and traded for resources. The result of this counter-economy was that prices based on supply and demand did not develop and many enterprises that would not have stayed in business otherwise survived. One study found that about 30 percent of timber industries were insolvent but remained in operation after independence (Papilla 1999). New actors also moved into the timber industry, including new Russian forest corporations, Russian businessmen and oligarchs, and foreign investors. In most cases ownership and production have become highly concentrated; in the case of pulp and paper mills about a dozen mills account for almost 75 percent of total output (Kortelainen and Kotilainen 2003; Torniainen et al. 2006). Leasing contracts were allocated for either 1-5 years or 1-49 years. Only the latter were based on competitive auctions between timber firms. The reservation price for a competitive auction was based on the quality of the timber stand and transportation costs, with the minimum reservation price based on the stumpage fee. The minimum stumpage fee was set in Moscow with regional administrators[2] setting the final stumpage fee.

Starting in 1985, regions began to take on an increasing amount of authority and responsibility both politically and economically in Russia (Hanson and Bradshaw 2000). A growing number of studies have used this regional heterogeneity to explore the divergence in economic and social outcomes across regions (Hanson and Bradshaw 2000; Yakovlev and Zhuravskaya 2004; Slinko et al. 2005; Yakovlev and Zhuravskaya 2008). Given the emphasis on privatization for revamping the economy of Russia, many studies have focused on how privatization impacted firm performance and economic growth. Several studies have found that regional differences in pro-reform policies and enforcement influenced the number of private enterprises and subsequently, the

[2] From 1993 until 1997 local administrators set the final stumpage fee, since then regional administrators have set final stumpage fee.

level of regional economic growth (Selowsky and Martin 1997; Berkowitz and DeJong 2002; Berkowitz and DeJong 2008). More recently, access to credit was identified as a main determinant of the number of private firms in a region (Berkowitz and De Jong 2008). State bureaucracy was also identified as impacting firm performance through its effect on privatization effectiveness, with larger bureaucracies providing better institutional support and less corruption (Brown et al. 2009).

III. Conceptual Framework

Institutions are the "rules of the game" and include both formal rules and informal rules or norms (North 1991). Rules are what constrain and allow individuals to act. Within post-Soviet Russia the rules were changing drastically. Within the forest sector rules about who could access and use forest resources and rules about who had the authority to allocate this land changed. The Institutional Analysis and Development (IAD) framework (Figure 1) provides a basic structure for analyzing institutional change. There are two main parts of the framework: the exogenous (referred to as "external" in the remainder of this paper) factors and the action arena. The action arena is conceptualized as a diverse space where participants interact, evaluate alternatives, exchange information and potential outcomes are created (Ostrom 2005). External factors include the biophysical world, material conditions, attributes of a community and rules. The external factors directly and indirectly impact the action arena. Ostrom (2005) proposes two uses of this framework. The first is to inquire about the external variables and how they impact the action arena. The second is to focus on the action arena and how actions within the arena are linked together.

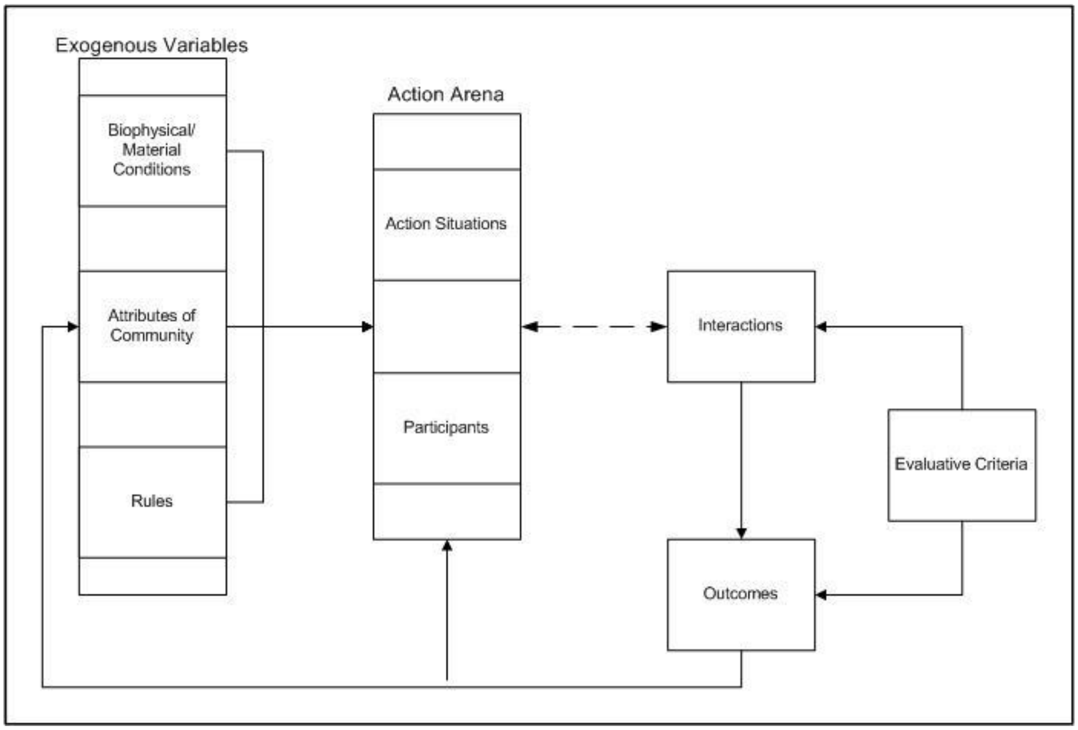

Figure 1. Institutional Analysis and Development Framework (author rendering)

The action arena in this study is the emerging market-based forest industry in Russia (Figure 2). In order to connect variables from the IAD framework to other parts of the paper I will label them here. Within this action arena forestry participants interacted with one another regarding the action situations. The primary action situation was the volume of timber harvested (HARVEST). As a result of privatization, timber was to be leased to private enterprises; thus, the amount of timber sold in a competitive auction was also an action situation (AUCTION) linked to HARVEST. AUCTION is hypothesized to positively impact HARVEST.[3] Forestry participants included regional and local employees (EMPLOYEE) of the Federal Forest Service and private timber enterprises (ENTERPRISE). The number of participants and their capacity should have impacted both action situations. However, whether the number or capacity of EMPLOYEE or ENTERPRISE had a positive or negative impact on these action situations is an empirical question. The primary outcome from these multiple interactions was the volume of timber harvested.[4]

[3] It is not possible to distinguish whether auctioned timber is cut in the same year of auction, or whether it is cut at all. Competitively auctioned timber is awarded for a 1-49 year lease period; non-competitive leases awarded for 1-5 years are not recorded in the measure of auctions used in this paper. The term auction implies competitive auctions for the remainder of this proposal.

[4] I cannot differentiate whether private firms or the forest sector cut timber recorded as harvested. According to the new institutions, commercial timber was to be leased to private firms; however, the federal forest service remained involved in timber harvesting legally through intermediate cutting and leasing land to other forest management units.

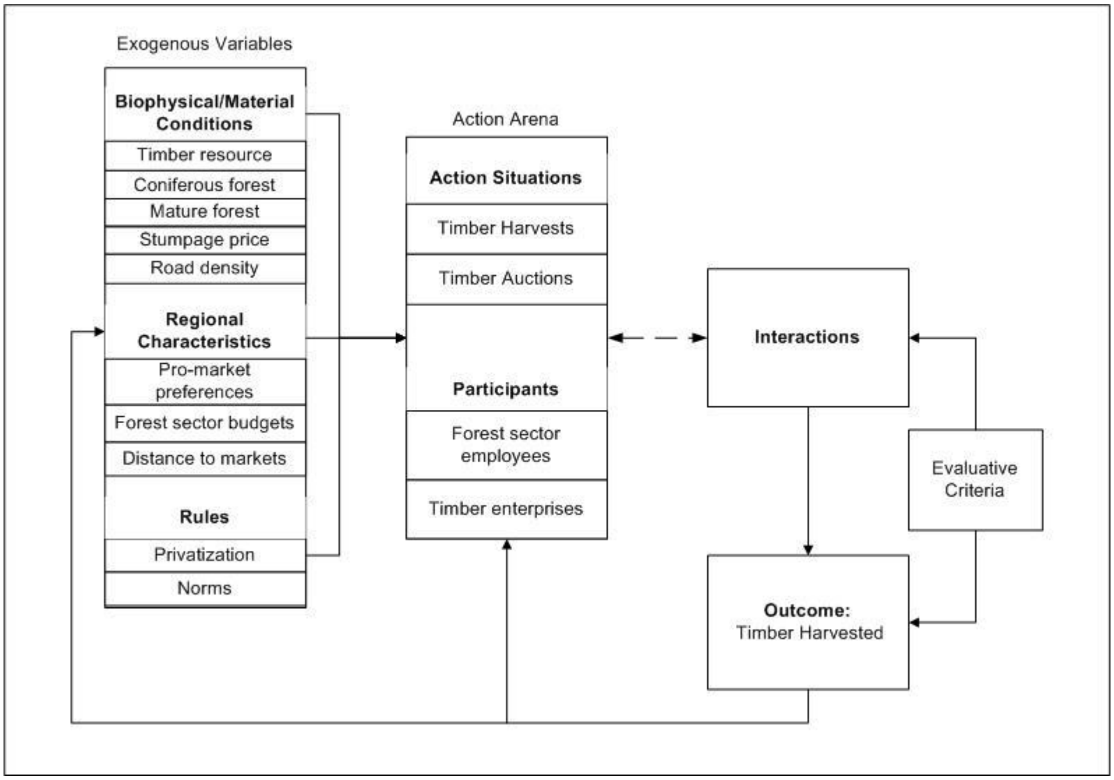

Figure 2. Emerging Market-Based Forestry Decisions in Russia (author rendering)

External variables directly and indirectly influenced the interactions of participants, action situations and the outcome, timber harvested. Starting with the category labeled rules, in this study the formal rules had been set: timber use was privatized and management decentralized. Given few substantive on-the-ground changes in forest sector decision-making, I focus exclusively on privatization as the rule impacting the action arena. The formal rules created the action situation of AUCTION and ENTERPRISE in this analysis. In addition to formal rules, informal norms influenced the development of the barter economy in Russia and interactions between forestry participants (Olsson 2008; Torniainen 2009). Taking these rules as a given, the objective of this study is to understand how other external factors interacted with these rules and with the action situations to lead to the observed outcome of timber harvested.

Biophysical and material conditions should have directly impacted the decision of how much timber to harvest and how much timber to lease. The initial timber resource (TIMBER) is expected to have had a positive effect on the volume of timber harvested and leased. The quality of timber should have also been important. Thus, the volumes of coniferous forest (CONIFER) and mature stock (AGE) are hypothesized to have positively impacted the volume harvested and auctioned. Stumpage price (PRICE) is also a reflection of timber quality. Stumpage prices were the base price used in competitive auctions and therefore should have impacted the volume of timber sold. A material condition important to volume of timber harvested and auctioned is access to timber stands. A common measure of access is road density (ROAD). More roads are hypothesized to have increased the volume of timber harvested and auctioned.

Community characteristics, or regional characteristics in this study, may have had indirect and direct effects on the action situations. Indirectly, the amount of federal budget (BUDGET) allocated to a region for forestry impacted the capacity and incentives of the Federal Forest Sector employees. This variation in capacity and incentives is hypothesized to have impacted how much timber was harvested or auctioned. ENTERPRISE might have also been affected by regional characteristics such as differences in pro-market reforms and institutional strength. For example, regional differences in pro-market reforms and institutional strength may have impacted the development of the barter economy within a region, levels of corruption within government agencies, or the location of foreign businesses. Whether or not timber firms were impacted by these regional characteristics is an empirical question that will be explored in detail in this chapter. A more direct impact of regional characteristics would have been their geographical location. The distance of a region (DISTANCE) to key markets such as Moscow and St. Petersburg is hypothesized to have had a positive effect on volume of timber harvested and auctioned.

IV. Study Region & Data

Study Region

This research focuses on the temperate forests of European Russia, where temperate coniferous, temperate deciduous and mixed forests dominate the landscape. Using World Wildlife Fund boundaries on ecoregion type, 36 unique regions fall within the temperate and mixed forest of European Russia. Since I am interested in harvesting activity, I omitted regions where harvesting volume was reported as zero for at least one year during the study period; these regions were all located along the southern border of the temperate zone. I also dropped Kalingrad since I expected it would be an outlier due to its unique history and location. The final study area for this research consists of 27 regions spanning three federal districts: Northwest, Central, and Volga (Part A, Figure 1).

Data

Data related to forestry in Russia, including HARVEST, AUCTION, PRICE, EMPLOYEE, and BUDGET come from a 2003 publication by the Federal Agency of Forestry of Russia entitled "Main Indicators of Forestry Activities 1988, 1992-2002". Data on TIMBER, CONIFER, and AGE come from the 1993 and 2003 State Registry of the Forest Fund. Data on ROAD and ENTERPRISE come from Russia's National Statistical Agency, Goskomstat Rossii. Distance calculations are made in ArcGIS. A description of all variables is presented in Table 1. Summary statistics are presented for data that has been analyzed.

Table 1. Summary Statistics (1993-2002)

Variables	**Description**	**Mean (Std Dev)**	**Min**	**Max**
Action situations				
HARVEST	The volume of timber harvested (m^3)	1,493,760 (1,629,759)	35,000	7,491,000
AUCTION	The volume of timber (m^3) sold at auction	178,180 (313,076)	0	2,373,100
Participants				
ENTERPRISE[5]	Number of forest enterprises	117.89 (74.895)	17	516
EMPLOYEE	Number of regional and local workers in Federal Forest Service	3,243.25 (1,478.36)	1,528	9,400
Biophysical & Material Conditions				
TIMBER	Total exploitable[6] timber volume (m^3)	253,000,000 (260,000,000)	16,000,000	1,080,000,000
CONIFER	Volume of exploitable coniferous timber (m^3)	Not summarized		
AGE	Volume of mature and overmature[7] timber (m^3)	Not summarized		
PRICE	Stumpage price (USD/ m^3)	2.10 (1.75)	0.00	9.94
ROAD	Kilometers of road per 1000 km^2 of territory	154.58 (58.78)	42.40	347.00
Regional Characteristics				
DISTANCE to Moscow	Kilometers	471.64 (273.76)	0.00	1,066.26
DISTANCE to St. Petersburg	Kilometers	847.18 (378.86)	0.00	1,551.21
BUDGET	Percent of budget coming from federal government	36.61 (24.47)	0.00	96.42

[5] I do not think number of timber enterprises is the right measures since it declines so rapidly over the study period – I discuss this more below. I am searching for data that will measure market power of enterprises such as output or number of employees.
[6] The Russian Federal Forest Service classifies total forest and exploitable forest in their inventories. I assume exploitable includes forests where commercial activities were allowed. I need to confirm with Russian colleagues that this is the correct interpretation.
[7] The Russian State Registry of Forest Fund classifies forest into four age categories: young, middle-aged, immature, and mature and overmature. I need to verify with Russian partners that mature and overmature is the primary target for commercial timber harvesting.

Currently, data cover 1993-2002; however, some variables in Table 2 did not have complete data over this time period. Information on ROAD was only available for 1990 and from 1995 to 2001. I assumed a linear trend and reconstructed road density for the years 1991 to 1994. For 2002 I assumed the same value as 2001[8]. Measures of the volume of exploitable forest (TIMBER), exploitable coniferous forest (CONIFER) and mature forest (AGE) were only available for two years: 1993 and 2003. Again, I assumed a linear trend and reconstructed the values based on the two given measures. Because of the lag in changing the rules, no regions reported timber auctions (AUCTION) until 1994 and it was not until 1995 that the majority of regions in this study started leasing. I recorded these missing values as zero since auctions became part of forest legislation in 1993.

V. Empirical Methods

Preliminary Descriptive Statistics

Action situations

The volume of timber harvested decreased and timber sold in competitive auctions increased between 1993 and 2002 (Figure 3). A spike in harvesting and auctioning occurred in the late 1990s following the Russian financial crisis.

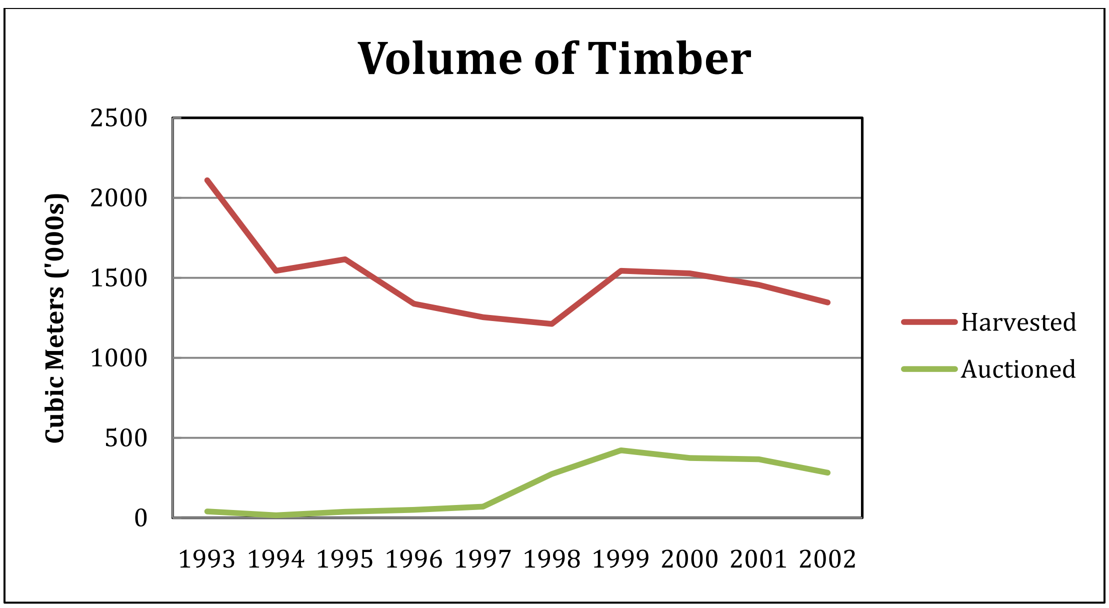

Figure 3. Trends in Volume of Timber Harvested and Auctioned from 1993-2002

[8] There should be data on road density after 2001, but I have not had the chance to search for it.

Trends in volume harvested and auctioned varied substantially across regions and year (Figure 4). Similar to Figure 3, regional levels of volume harvested dropped in the early years following independence but started picking up again around 1999. The volume of auctioned timber increased in the late 1990s but dropped slightly in the early 2000s.

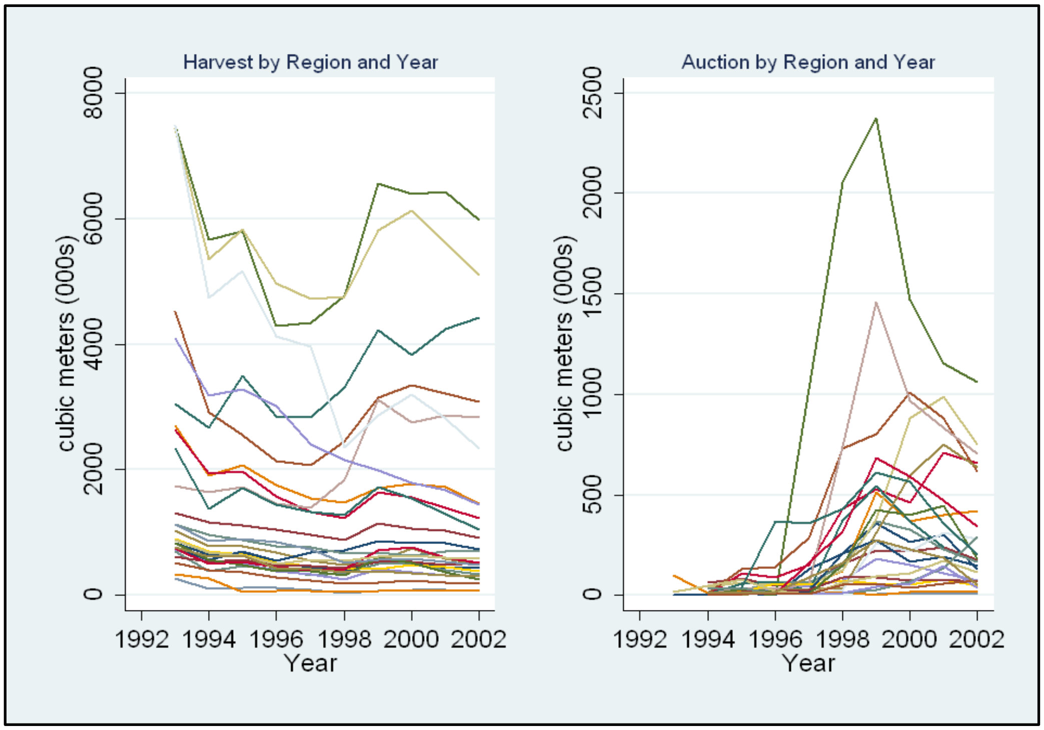

Figure 4. Trends in Volume of Timber Harvested and Auctioned by Region and Year

The volume of timber harvested was positively correlated with the volume of timber sold in auction (Figure 5). However, substantial clustering on the left-hand side of the graph indicates that this correlation might be driven by a few observations.

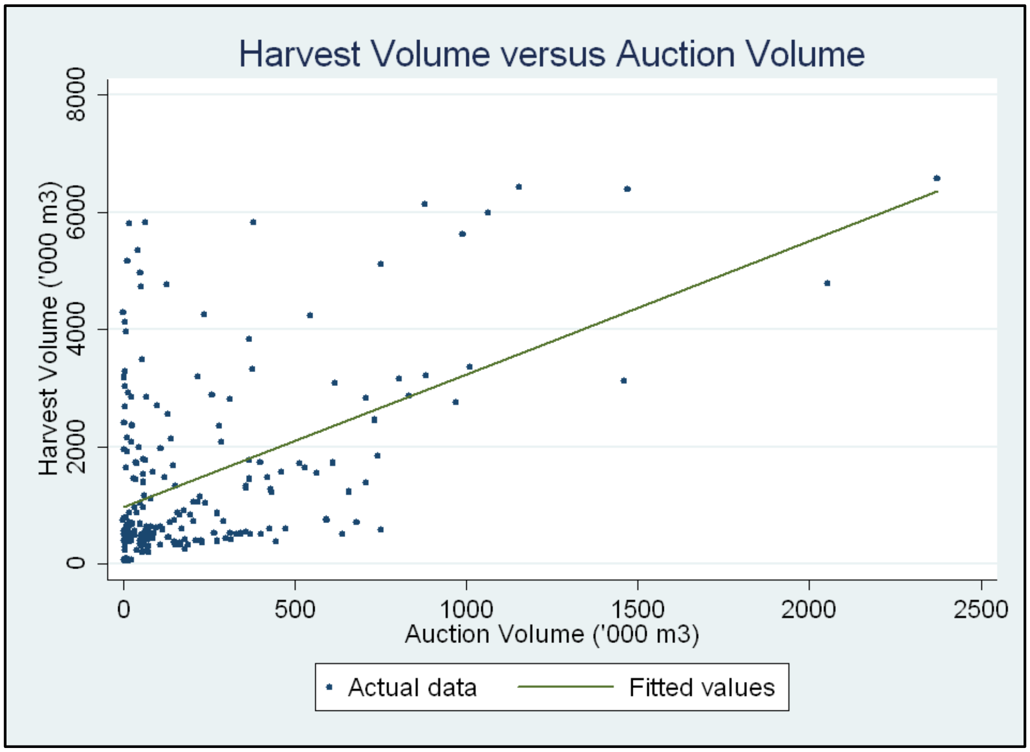

Figure 5. Relationship between Timber Harvested and Auctioned

<u>Participants</u>

Despite changes within the state forest sector after independence, the number of employees did not change much between 1993 and 2002 (Figure 6). This was not the case for the number of private timber enterprises, which decreased considerably over these ten years. This decrease in the number of firms might be a result of the high level of bankruptcy that followed transition and or the large amount of consolidation that occurred within the timber industry (Kortelainen and Kotilainen 2003; Torniainen et al. 2006). Additional information on firm consolidation and market power is needed to understand why the number of timber firms changed so drastically in Russia during this time.

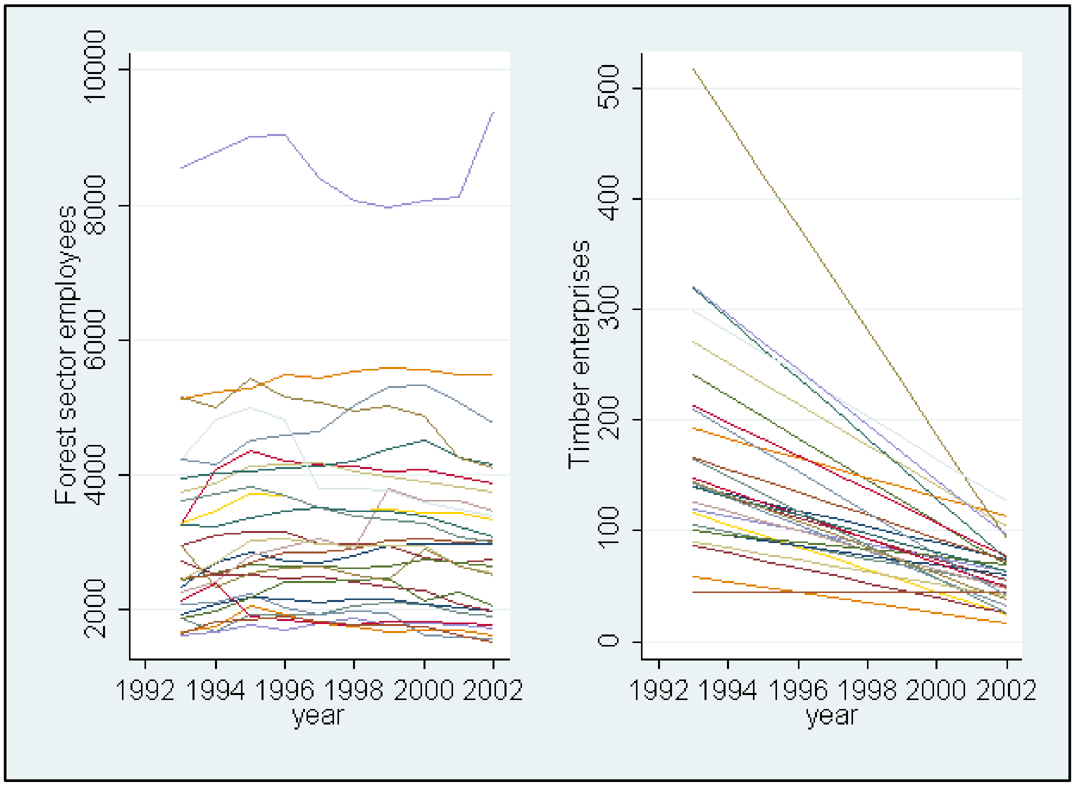

Figure 6. Number of Employees and Timber Enterprises

External variables

Biophysical resources in the study region did not change much over the first decade of independence (Table 2). Total forest area and growing stock increased during these ten years. However, the exploitable area and growing stock – defined as forestland allocated for commercial use – decreased. Changes in volume and area hide regional variations: exploitable growing stock increased in 13 out of 27 regions and exploitable area increased in 7 out of 27 regions.

Table 2. Trends in Total Timber Area and Volume

	1993	2002	Gross Change	Percent Change
Total Forest Area (ha)	54,700,000	56,700,000	+ 2,000,000	+ 3.66
Total Exploitable Area (ha)	48,300,000	45,300,000	– 3,000,000	– 6.21
Total Forest Volume (m^3)	8,060,000,000	8,820,000,000	+ 760,000,000	+ 9.43
Total Exploitable Volume (m^3)	6,920,000,000	6,770,000,000	– 150,000,000	– 2.17

Road density increased slightly in all regions throughout the study period, but initial road coverage was different across regions (Figure 7). More dramatic changes occurred in stumpage prices (Figure 8) and forest sector budgets (Figure 9) from 1993 to 2002. Stumpage prices increased over time, probably reflecting learning on the part of the forest sector. Forest sector budgets decreased rapidly as the government shifted budgetary responsibilities to the regional and local level.

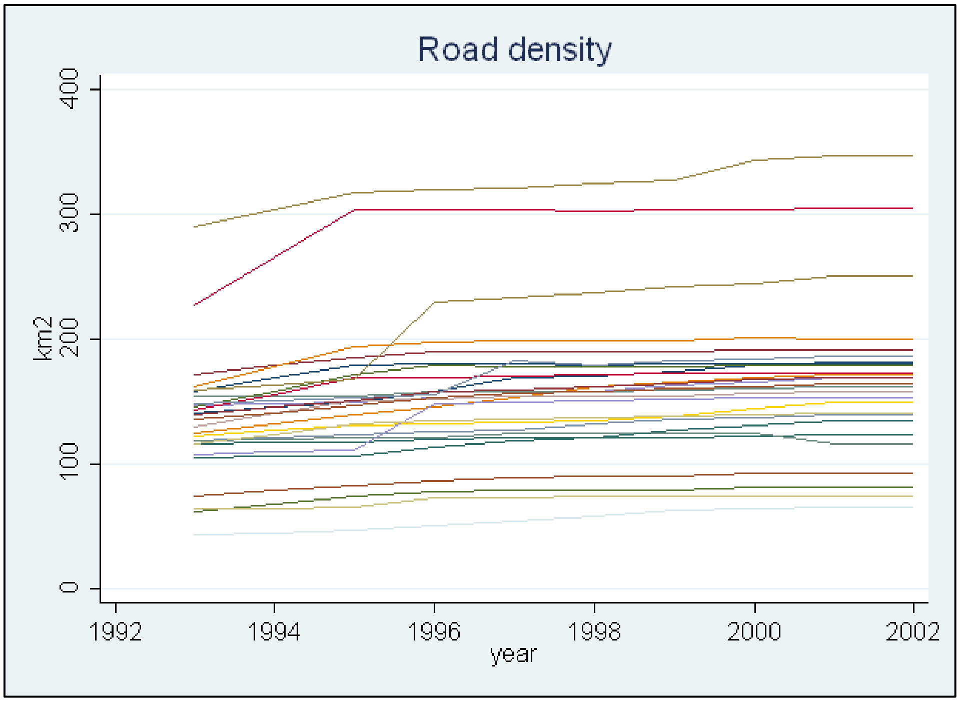

Figure 7. Road Density

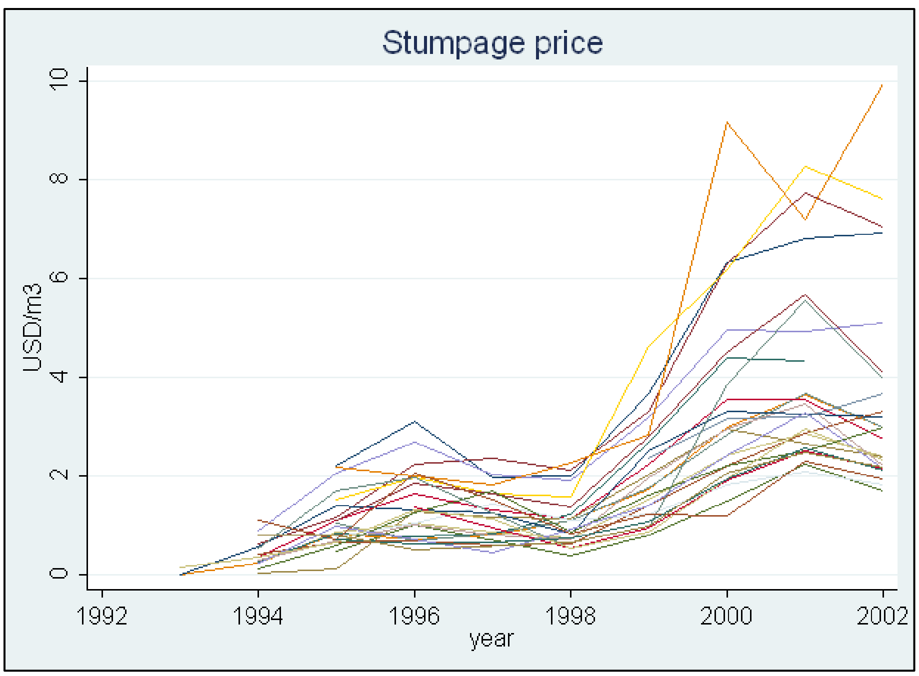

Figure 8. Stumpage Prices

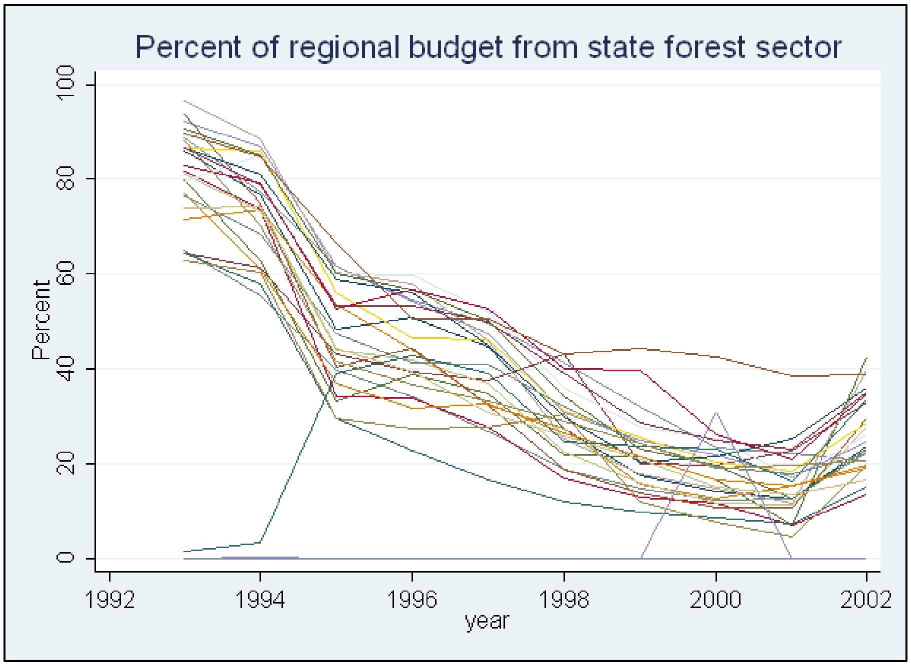

Figure 9. Percent of Forest Sector Budgets from Federal Government

Correlations between the action situations, participants and external variables indicate the strength of univariate relationships (Table 3). The effect of many independent variables switches from negative to positive, or vice versa, across the two action situations. A strong and positive correlation is found between TIMBER and the volume of timber harvested and auctioned. The action situation HARVEST is also positively correlated with the number of forest participants (ENTERPRISE and EMPLOYEE) and volume of timber auctioned (AUCTION). The strength of the correlations between the action situation AUCTION and external variables is weaker, but BUDGET and DISTANCE are negatively correlated with the volume of timber auctioned.

Table 3. Correlations between Action Situations and Independent Variables

	Harvest Volume (m3)	**Auction Volume (m3)**
ENTERPRISE	0.466	-0.123
EMPLOYEE	0.334	0.001
TIMBER	0.925	0.351
PRICE	NA	0.032
ROADS	-0.543	-0.048
DISTANCE to Moscow	0.323	-0.103
DISTANCE to St. Petersburg	-0.123	-0.275
BUDGET	-0.024	-0.355
AUCTION	0.393	NA

Econometric Analysis

Action situations

The next step of this analysis is to use econometrics to test hypotheses about the conceptual framework (Figure 2). Given variations over regions, *i*, and time, *t*, I will estimate a two-way linear effects model for timber harvested and auctioned. A two-way effects model allows for region- and time-specific effects (Cameron and Trivedi 2005).[9] While regions and time are allowed their own intercept terms in these models, slopes are the same across regions.[10] For timber harvested I will estimate[11]:

$$HARVEST_{it} = \alpha_i + YEAR_t + \gamma_1 TIMBER_{it} + \gamma_2 AUCTION_{it} + \gamma_3 CONIFER_{it} + \gamma_4 AGE_{it} + \gamma_5 ROAD_{it} + \gamma_6 EMPLOYEE_{it} + \gamma_7 ENTERPRISE_{it} + \gamma_8 BUDGET_{it} + \gamma_9 DISTANCE_{Moscow\ i} + \gamma_{10} DISTANCE_{St.Petersburg\ \ i} + \varepsilon_{it} \quad (1)$$

And for timber auctioned I will estimate:

$$AUCTION_{it} = \alpha_i + YEAR_t + \gamma_1 TIMBER_{it} + \gamma_2 PRICE_{it} + \gamma_3 CONIFER_{it} + \gamma_4 AGE_{it} + \gamma_5 ROAD_{it} + \gamma_6 EMPLOYEE_{it} + \gamma_7 ENTERPRISE_{it} + \gamma_8 BUDGET_{it} + \gamma_9 DISTANCE_{Moscow\ i} + \gamma_{10} DISTANCE_{St.Petersburg\ \ i} + \varepsilon_{it} \quad (2)$$

The intercepts, α_i, are random variables that capture unobserved region-specific heterogeneity; two-way effects models with random intercepts can be estimated using the fixed or random effects model. If the α_i are correlated with any of the observed covariates in the model, then a fixed effects model is the consistent estimator. Including fixed effects adds an intercept term for each region to the model. If the α_i are distributed independently of the covariates in the model then a random effects model is the consistent estimator. In modern econometrics the fixed effects model is often preferred because the stronger assumptions required by the random effects model are

[9] I will also consider using a one-way region-specific effects model that allows random intercepts for regions only. However, given the temporal shocks during the transition period a two-way effects model is probably preferred.
[10] Random slopes can be incorporated into the two-way effects model. The applicability of incorporating random slopes will be decided based on analysis of the data.
[11] I will also consider including lagged variables as covariates in this model; particularly in the case of auction volume where the amount auctioned may not be harvested in the same year. The major disadvantage of using lagged variables is that it would reduce the total number of observations.

usual untenable (Cameron and Trivedi 2005). One disadvantage of the fixed effects model is that time-invariant regressors cannot be identified. In Equations 1 and 2 this would affect measurement of $\gamma_9$and γ_{10}. The presence of fixed effects can be tested for using the Hausman test. The Hausman test determines whether there is a statistically significant difference between the fixed and random effects models. The preferred model can be estimated using generalized least squares[12]. The time-specific effects – $YEAR_t$– will be treated as fixed effects in both models and estimated using time dummies.

The efficiency of the slope estimates is affected by the error term, ε_{it}. Specifically, valid statistical inference is affected by: 1) serial correlation (correlation over *t* for given *i*), 3) heteroscedasticity, and 3) spatial correlation (correlation across *i*). The fixed and random effects models can reduce serial correlation in the errors, but a more robust and standard approach is to use panel-robust standard errors (Cameron and Trivedi 2005). Panel-robust (also known as cluster-robust) standard errors control for all functional forms of serial correlation and control for heteroscedasticity. In many microeconometric applications spatial correlation is not a concern, but it is a concern in many geographic applications. Formal tests can be used to rank correlation across subjects such as Anselin's Moran's-I statistic (Anselin 1999). If spatial correlation is a concern it can theoretically be corrected for by weighting the covariance estimates. In the past, this was done by using some type of distance-based criteria such as the Euclidean distance between regions or a weighting based on congruence; these models are referred to as spatial autoregressive error (SAR) models (Anselin 1999; Anselin and Bera 1998). A more recent strategy that has emerged is to use cluster-robust standard errors that allows for spatial correlation within clusters (Gellrich et al. 2007; Muller and Munroe 2008; Horsch and Lewis 2009). If the fixed effects model is used, however, all time-invariant unobservables are controlled for and spatial correlation across regions should not be a concern.

The two-way effects models in Equations 1 and 2 will not be correctly estimated if the assumption of strict exogeneity is violated. In many econometric applications this assumption is violated and extensions to the basic linear model are necessary (Cameron and Trivedi 2005). Endogeneity occurs when an independent variable is correlated with the error term and it results in biased estimators. Endogeneity has many causes, some of the most common are: omitted variables,

[12] I will also consider nonlinear estimation in the case of timber auctioned since many regions do not report a volume for timber auctioned before the mid-1990s; thus timber auctioned takes the value zero for many observations. A censored regression model such as the Tobit can be used when the dependent variable is not completely observed.

simultaneity bias, and measurement errors. The panel data structure affords some advantages over cross-sectional models in controlling for endogeneity. Specifically, if the fixed effects model is used then endogeneity bias caused from time-invariant unobservables is mitigated; however, time variant unobservables are still a concern. If the random effects model is used then addressing endogeneity becomes more critical. One of the primary methods used to deal with endogenous regressors is to use instrumental variables. A valid instrument is a variable that is correlated with the endogenous variable but uncorrelated with the error term. Instruments can be variables that do not occur in the original equation of interest or can be lagged variables from the original equation. While correcting for endogeneity bias is important for causal analysis, identifying an instrument is not always straightforward and using a weak instrument can also introduce bias into the regression (Cameron and Trivedi 2005).

Given the importance of the exogeneity assumption in correctly estimating Equations 1 and 2, it is important to discuss any potential endogeneity problems. EMPLOYEE and BUDGET should be strongly correlated with total forest cover in a region; however, both are artifacts of Soviet legacy and may have some political explanation originating in the Soviet era. For example, the region with the most employees had one of the lowest percents forest cover. Despite this anomaly, there is no foreseen correlation between number of forest sector employees – which did not change much over the study period (Figure 6) – and the error terms. The allocation of federal budgets changed substantially across time, but the decline was similar across most regions (Figure 9). Discussions with Russian forest experts suggest that budget allocations did not correspond with volume of timber harvested (Laestadius, personal communication); so there would have been little incentive to cut more trees to receive more federal budget. The data do suggest, however, that oblasts and republics received different amounts of the federal budget following independence, with republics receiving much less. This is most likely related to differences in fiscal autonomy – specifically the ability to collect taxes and revenues – granted to republics and oblasts after independence. Differences in fiscal incentives might have indirectly affected harvesting or auction decisions, suggesting that controlling for whether a region is an oblast or republic would be important if the random effects model is used. This can be done with a dummy variable. If the fixed effects model is used then this time invariant factor would be controlled for by the panel data structure. ROADS and DISTANCE do not pose any foreseeable endogeneity concerns.

ENTERPRISE changes substantially across regions and time (Figure 6). One explanation for these changes is that a number of firms went bankrupt during the transition period; many because they could not gain access to credit (Torniainen 2009). However, other literature suggests that many insolvent firms remained in operation due to the barter economy that developed (Papilla 1999). Another explanation for the decline in the number of firms is that the industry consolidated due to economies of scale. Under ideal conditions, the transition to a market-based forest sector should have led to the efficient number of timber firms. However, the transition in Russia was not ideal due to a lack of supporting mechanisms and weak institutions, so little can be inferred about what the number of timber firms means. Most of the literature on privatization in Russia focuses on the growth in private enterprises since, in general, the number of private firms was increasing across Russia. Thus, the case of the timber industry – declining number of private firms – might be particular to the natural resource industry. To gain more insight on whether the decreasing number of timber firms reflects industry consolidation or something else, I am currently searching for measures of timber firm capacity and output.

Regardless of whether ENTERPRISE in Equations 1 and 2 is measured as the number of firms or the market power of firms, correlation could exist between this covariate and the error term. As discussed in the conceptual framework, regional characteristics such as pro-market preferences and institutional strength may have impacted the number or capacity of firms, and may have also led to different volumes of timber harvested or auctioned. I have found no reference that elaborates on how regional conditions affected firm development within the timber industry. Thus, whether and how regional characteristics influenced the number or capacity of timber firms is an empirical question. One of the goals of this chapter will be to shed light on the relationship between regional characteristics and firm size or capacity; this is described in the next section. If regional characteristics did impact the size or capacity of timber firms and the random effects model is used, instrumental variables will be needed for ENTERPRISE. If the fixed effects model is used then these regional characteristics, assuming they are time invariant, will be controlled for.

The measure of AUCTION could also pose endogeneity concerns in Equation 1, if, similar to ENTERPRISE, regional characteristics such as pro-market preferences or institutional strength affected competitive auctions as well as the volume of timber harvested. Anecdotal evidence suggests that high fees and bribes (i.e., corruption) charged by some forest sector employees were a major deterrent to lease agreements (Yaroshenko, personal communication); forest sectors that were more likely to engage in this type of behavior may have also had different harvesting preferences. The empirical question is whether these types of engagements were imbedded in larger regional norms and preferences, or whether they were specific to employees and are captured by variables such as BUDGET that measures the financial incentives faced by the forest sector. Estimation of Equation 2 should help inform whether region-specific effects are present in the auction decision. If there is indication that regional characteristics pose an endogeneity concern to Equation 1 and the random effects model is used then stumpage prices and the other covariates in Equation 1 can be used to instrument for volume of timber auctioned.

PRICE only appears in Equation 2 since it is the base stumpage price set by the regional forest service and served as the minimum reservation price in a competitive auction. Thus, PRICE does not capture the high fees and bribes that forest service employees passed on to timber firms. In general, official stumpage prices were criticized as being too low in Russia and constituted a small percent of the operating costs for a timber firm (Jacobsen 1999). Given the fact that PRICE does not account for illegal fees, there is no foreseeable concern that PRICE is correlated with the error term in Equation 2. To further mitigate these concerns, a panel model will be estimated to determine the effect timber quality, timber quantity, transportation costs and other unexplained factors had on stumpage prices.

Endogeneity bias can also come from measurement error. Measures of the volume of timber, conifers and mature forest are subject to measurement error given findings that measures of growing stock in Russia are inaccurate (Kinnunen et al. 2007). An instrumental variables approach to addressing this problem is to use multiple measures of forest to correct for errors in measurement (Wooldrige 2009). Since I have national statistics on both volume and area of TIMBER, CONIFER and AGE, I can use one of these variables to instrument for the other.

Participants

Pending data, a supplementary objective of this chapter will be to analyze how the number and market power of timber firms changed over the study period. The objective of this analysis will be to determine how much consolidation occurred within the timber industry and provide information on how factors other than timber resources impacted the number and size of timber firms that emerged following privatization. To do this I will use a combination of open-ended discussions with Russian forestry experts, descriptive statistics and linear regressions. The outcome of this inquiry will be a description of privatized timber firms in Russia that will inform the estimation strategy for Equations 1 and 2 in this chapter and estimations in Chapter 2.

Several studies interested in the impact of private enterprises on regional economic growth in Russia argue that the number of private firms was endogenous to growth since both were influenced by unobservable regional characteristics (Berkowitz and DeJong 2003, 2008). These studies use the percent of votes for pro-reform parties in the 1993 legislative elections in Russia to instrument for the number of private enterprises in 1995. These same studies argue that after 2000, a valid instrument for the number of firms is the amount of credit available. The shift from voting patterns to credit is based on the argument that political preferences were no longer as clearly pro-reform versus pro-communist after a decade of independence and that credit opportunities only emerged at the turn of the century. Another study finds that the size of the regional bureaucracy had a statistically significant impact on privatization effectiveness (Brown et al. 1999).

In the case of timber firms, it is not clear whether these regional characteristics had a significant impact on their development. One argument is that regional characteristics such as pro-reform policies and institutional strength would have affected the number or capacity of timber firms and that these same regional characteristics could have also influenced the volume of timber harvested or auctioned. Pro-reform preferences that led to more support for private firms and better business regulations might have created a more competitive environment for timber firms. This might have led to bankruptcies when they were efficient and kept them from occurring when they were inefficient. A more robust business environment might have also impacted foreign investments and foreign ownership of timber firms. Foreign ownership has been associated with positive economic growth in Russia (Brown et al. 2009). Corruption within the forest sector, which could have impacted firm numbers and size, and is thought to have impacted harvesting and auctions, might have been influenced by the overall regional bureaucratic climate. If these regional characteristics are thought to have had an impact then using instruments such as voting patterns or access to credit would be important in a random-effects model of timber harvested and auctioned.

An alternative argument for timber firms is that the number and capacity of firms were a function of the biophysical attributes – e.g., quality and quantity of forest resources – and access – e.g., roads – but that other regional characteristics did not play a role in their development. I would then expect to find more consolidation (market power) of firms in heavily forested regions due to economies of scale. The number of firms would also be expected to decrease in these regions due to competition. I would also expect to find that regions with more forest and better access attracted more foreign investors, regardless of the regional business or political environment. Under this explanation, corruption within the forest service could be explained by the perverse incentives placed on employees by cuts in federal budgets, and not by political or cultural regional characteristics. If this latter story is the case then including ENTERPRISE in Equations 1 and 2 should not introduce endogeneity concerns, even if the random effects model is used.

VI. Expected Outcomes & Significance

This research will test descriptive hypotheses about how changes to forest institutions, specifically the privatization of timber enterprises and the use of competitive auctions, impacted the volume of timber harvested in the temperate and mixed forests of European Russia. This will be the first study to analyze the determinants of harvesting for such a large number of Russian regions and over such a long time period. Results from this analysis will be used to inform causal hypotheses in Chapter 2. Findings from this work will be summarized into a paper for the journal Eurasian Geography and Economics.

B.2. Chapter 2: A spatial analysis of timber harvesting decisions from 1990-2005

Research Questions:

What determined timber harvesting rates in post-Soviet Russia?

What factors are associated with unreported logging?

How would changes to forest institutions and incentives affect future harvesting?

I. Overview

In Chapter 2 I will expand on the conceptual and descriptive results of Chapter 1 to test causal hypotheses about timber harvesting decisions and to estimate future harvesting rates under changes to forest institutions and incentives. Specifically, in this chapter, I will use remotely-sensed data on the area of timber harvested in econometric models to analyze the impact of district- and region-level regressors on the area of timber cut. Estimates from these models will be used to forecast timber harvesting until 2030. This chapter will contribute to a growing body of science that combines remote sensing data with socioeconomic information to model land-use decisions. It will be the first study to combine remote sensing data on forest clearing with socioeconomic drivers for a large region in post-Soviet Russia[13]. Thus, it will provide valuable information on the impacts of post-Soviet forest institutions on timber harvesting decisions and quantify the impact of these new policies on reported and unreported harvesting levels. In addition, it will provide estimates of expected changes in forest harvesting if current institutions and incentives are restructured.

The study area for this chapter will be the 27 regions identified in Chapter 1. The dependent variable in this study will come from remotely sensed land-cover data generated by South Dakota State University's Geographic Information Science Center of Excellence using an automated

[13] I have found one paper that uses remote sensing analysis without socioeconomic modeling to look at land-use change in Russia's forests (Boentje and Blinnikov 2007) and one paper that uses socioeconomic modeling but focuses on a small area in Siberia (Peterson et al. 2009).

classification approach (Potapov et al. *in review*). The area of forest disturbance will be aggregated to the district level[14]. Independent variables will be similar to those identified in Chapter 1, and where possible, data will be collected at the district level. Given the dependence of district-level harvesting decisions on regional-level characteristics, a multilevel linear model – also known as the hierarchical linear model or random coefficients model – will be used for estimation. Multilevel models are considered more efficient than simple linear models when data have a hierarchical structure or are acquired through a multistage sample design. This is because conventional statistical approaches assume independence between levels and often include aggregated or disaggregated data, which requires assumptions about scale effects (Overmars and Verburg 2006). A number of recent land-use change studies have used multilevel analysis to account for hierarchical structure, including: Hoshino (2001), Polsky and Easterling (2001), Pan and Bilsborrow (2005), Vance and Iovanna (2006), and Overmars and Verburg (2006). Multilevel models relax the assumptions of independence between observations by decomposing the error term into hierarchical components and then imposing a structure on the variance and covariance of these terms (Anselin 2002). If the spatial dependency is only related to the nested hierarchy of individuals and groups, then multilevel analysis can control for all correlation between observations (Overmars and Verburg 2006).

Several econometric specifications will be estimated in this chapter. First, I will evaluate the determinants of the total area of timber harvested at the district level. Forecasts of future harvesting will be based on this specification and scenarios will be developed around possible changes to forest institutions and economic incentives that could impact harvesting rates. Second, I will approximate the area of timber legally and illegally harvested at the regional level by comparing forest disturbance from remote sensing to harvesting reported in national statistics. These estimates will be approximations at best given differences in measurement – remote sensing gives area harvested whereas national statistics report volume harvested. However, even a rough approximation should provide information about the magnitude of illegal harvesting that occurred in post-Soviet Russia and econometric models will be used to describe the type of factors related to the unreported area of forest disturbance.

II. Conceptual Framework

In Russia, the forest sector was transitioning from a command-and-control system of timber allocation to a competitive market where supply and demand determined optimal timber allocation. A competitive market can be defined as: "a decentralized collection of buyers and sellers whose

[14] There will be at least 300 districts in the analysis.

interactions determine the allocation of a good or set of goods through exchange" (Keohane and Olmstead 2007, p.56). This definition implies that buyers and sellers come together on their own and that there is an exchange of payment for goods and services. Three conditions are required for the market equilibrium to be considered the efficient solution: buyers and sellers must be price takers, they must have good information about the quality of the good, and they must bear all relevant costs and benefits of the transactions (Keohane and Olmstead 2007). The latter condition implies that property rights are well-defined and enforceable. A well-defined property right is transferable, secure and excludable (Schlager and Ostrom 1992). Under these conditions, the economically efficient approach to timber management is to maximize the present value of the stand.

The Faustmann formula gives the present value of a stand under infinite rotation. The Faustmann formula can be used to derive the optimal rotation period of the stand, known as the Faustmann rotation. Assuming an even-aged stand, the Faustmann formula is:

$$\max \pi = \frac{PQ(T)-C}{(e^{\delta T}-1)} \tag{1}$$

where:

π=profit

P=timber price

Q(T)=volume of timber at time, T

C=replanting costs

δ=discount rate

The optimal rotation period is found by taking the first order condition and solving, which gives:

$$P\frac{dQ(T)}{dT} = [PQ(T) - C]\delta + \delta\pi \tag{2}$$

The left-hand side of this equation is the marginal benefit of waiting to cut. The right-hand side is the marginal cost of waiting to cut and consists of two parts: the foregone interest from not cutting the stand and the rental value of delaying all future harvests on the land (Conrad 1999).

There were at least two reasons why the economically efficient solution to timber harvesting was not achieved in post-Soviet Russia. First, a competitive market requires an exchange of payment for goods and services. This process broke down in Russia and instead of hard budget constraints and prices determined by supply and demand, a system of barter and trade developed referred to as the "virtual economy" (Gaddy and Ickes 1998; Olsson 2008). A study of eight Russian regions found that only six percent of enterprises were displaying market-oriented behavior as of 1998 (Olsson 2008). Second, property rights were not well-defined in Russia since leases were not transferable and the duration of leases was less than 50 years. Given average rotation periods of around 50 to 60 years for deciduous species and 80 to 90 years for coniferous species in Russia (Yaroshenko, personal communication), a long-term lease was inadequate for multiple rotations and thus the opportunity costs of delaying future harvests were not internalized by decision-makers. In addition to the lack of incentives to invest in regeneration, no legal responsibilities to reforest were transferred to leaseholders until the 2007 Forest Code (Torniainen 2009).

Given these conditions, the problem faced by a decision-maker was more akin to maximizing the present value from a single rotation. The optimal single rotation period for a timber stand can be represented by the following maximization problem:

$$\max[PQ(T)e^{-\delta T}] \tag{3}$$

Which has the solution:

$$P\frac{dQ(T)}{dT} = \delta PQ(T) \tag{4}$$

The left-hand side of Equation 4 is again the marginal benefit of waiting to cut and the right-hand side the marginal cost of waiting. Equation 4 can be rewritten as: $\frac{dQ(T)/dT}{Q(T)} = \delta$. Thus, the optimal time to cut is when the rate of return from the stand equals the rate of return elsewhere in the economy. The optimal time to cut under a single rotation is typically longer than under the Faustmann rotation. Achievement of the optimal single rotation in Russia was also hindered by the development of the virtual economy and incomplete property rights. Incomplete property rights often decrease the time to harvest since the marginal benefits of waiting are reduced by uncertainty of tenure. However, at least for legal harvesting, factors such as the rate of return elsewhere in the economy probably had a larger effect on length of rotation period and thus the quantity of timber harvested. Specifically, Russia was plagued by hyperinflation in the early 1990s. The low value of the ruble would have decreased the marginal costs of waiting to cut, increasing the rotation period. The marginal benefit from waiting would depend on the age and species of timber on the stand.

The decision to cut in any given year would have been based on an assessment of the rents from harvesting a stand, *i*, at time, *t*. Formally, a decision-maker choosing to cut timber or not to maximize rents can be represented as:

$$max_{it} R_{it} = P_{it} * Q_{it} - W_{it} * I_{it}, \tag{5}$$

where:

P_{it} = output prices for timber

Q_{it} = quantity of timber harvested

W_{it} = input costs

I_{it} = inputs used in harvesting

Thus, timber is cut if:

$$R_{it,cleared} > R_{it,uncleared} \tag{6}$$

Higher P_{it} and lower W_{it} raise returns to the decision-maker and should lead to more harvesting. While P_{it} and W_{it} are not directly observable, biophysical characteristics (g_{it}) of the stand and socioeconomic characteristics (s_{it}) can be used as proxies for output and input prices. Specifically, the quality of timber resource on the stand, as well as transportation costs, impact prices. The choice of Q_{it} conditional on P_{it} and W_{it} is affected by the level of effort (e_{it}) and the amount of resource stock available (f_{it}). There were two actors involved in timber harvesting decisions: private timber firms and federal forest service employees. The number and capacity of both actors should have impacted the quantity of timber harvested. The quantity of timber available depends on the age and type of timber growing on the stand. I_{it} includes equipment and machinery and is assumed static over space and time in this study. Note that Q_{it} is not directly observed using remote sensing data, but whether or not the stand is cleared, H_{it}, can be used as a proxy. The stand-level decision rule can thus be written as:

$$H_{it,cleared} \left(g_{it}, s_{it}; e_{it}, f_{it}\right) > 0 , \tag{7}$$

where:

$$H_{it,cleared} = R_{it,cleared} - R_{it,uncleared} \tag{8}$$

In Russia, while timber harvesting occurred at the stand level, decisions regarding the amount of timber to be harvested (including how much timber was leased to private timber industries and the number of forest sector employees) were made at the local and regional level.

Therefore, I will aggregate stand-level decisions to the district level[15]. Equation 7 can be aggregated to the district level, which gives Equation 9:

$$H_{jit,cleared}\,(.) = H_{jt,cleared}\,(.) - \varepsilon_{jit}\,, \tag{9}$$

where *j* is a district and ε_{jit} is the difference in profits if stand *ji* is cleared or not in time *t*. Thus, a timber stand is cleared in a district in a time period if and only if:

$$H_{jt,cleared}\,(.) > \varepsilon_{jit} \tag{10}$$

Additional socioeconomic characteristics at the regional-level are hypothesized to have impacted harvesting decisions. First, while private timber firms faced formal auction prices and timber fees, captured by g_{it} and s_{it}, high informal fees placed on private timber firms increased their operating costs and reduced the amount of legally harvested timber (Torniainen 2009). The area of timberland leased can be used to gauge whether the new market-based instrument for allocating timber was being used and thus, whether informal processes or fees were prohibitive. Lack of enforcement of formal rules and fees, and opportunities to acquire timber through bribes, may have increased illegally harvested timber. Second, despite the adoption of leasing mechanisms by the Russian forest sector, local forest management units (FMU) were still allowed to harvest and sell timber from intermediate cuttings. These cuttings were a major source of income for FMU following cuts in federal budgets, and as of 2006 they still accounted for more than one third of all timber harvested (Petrov 2007). Thus, the amount of federal budget allocated for forestry should have affected harvesting rates. Some of these intermediate cuttings were technically illegal in that there was no silvicultural need for sanitary cutting or thinning (Eikeland et al. 2004). The involvement of FMU in timber harvesting and selling had additional impacts on the competiveness of private firms since FMU did not have to pay formal or informal forestry fees and taxes associated with lease contracts (Torniainen 2009).

[15] While local forest management units (FMU) followed district political boundaries in most cases, some districts had multiple FMU operating within them. However, given the approximate correspondence between the two boundaries (Yaroshenko, personal communication) and the presence of socioeconomic data at the district level, I will utilize district-level boundaries for this research.

III. Data

Dependent Variable

The dependent variable for this study will be continuous: the gross area of timber harvested within a district.[16] These data have been generated by an automated classification process that measures forest change with 30-m resolution Landsat footprints[17] (Potapov et al., *in review*; Boreal Forest Monitoring project); I will aggregate these data up to the district level. The area of forest change has been measured for two time periods: 1990 to 2000 and 2000 to 2005. However, given the nature of remote sensing analysis, some variation in the composite images is to be expected. For example, the 2000 to 2005 change product uses images from 1999 to 2002 to measure 2000 forest cover and images from 2003 to 2005 to measure 2005 forest cover (Boreal Forest Monitoring project).

Independent Variables

Independent variables follow the conceptual model outlined in Section II (Table 1). Biophysical variables expected to influence timber harvesting include: total forest area, area of specific forest types (e.g., coniferous), area of mature and overmature[18] forest, and slope. These variables impact the relative benefits and costs of harvesting a particular stand and the total quantity of timber on the stand. Socioeconomic characteristics expected to influence benefits and costs from harvesting and the level of effort at a stand include: road density, distance to markets, number of forest sector employees, number of firms, federal budgets and area of timberland leased. All data are available at either the district or regional-level. [19]

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[16] I will also analyze the percent change in forest harvesting from the base year (i.e., 1990 and 2000) as a dependent variable. Thus, I will calculate the percent of forest cut from the 1990 forest cover level and use this as the dependent variable; however, I will need to consider the applicability of using both percent changes in the same econometric model since the time periods do not correspond exactly (i.e., one is a ten-year change and the other a five-year change). There might also be an opportunity to get annual rates of forest clearing for the 2000 to 2005 period, in which case this type of dependent variable could easily be analyzed on an annual basis for these years. For the remainder of this chapter proposal I will discuss analysis of the gross area of forest cleared from 1990 to 2000 and 2000 to 2005 as the dependent variable.

[17] A satellite view is referred to as a footprint. Since satellite data used in this analysis came from the Landsat satellite program they are referred to as Landsat footprints or Landsat images.

[18] The Russian State Registry of Forest Fund classifies forest into four age categories: young, middle-aged, immature, and mature and overmature. I need to verify with Russian partners that mature and overmature is the primary target for commercial timber harvesting.

[19] Most of the socioeconomic variables are only available at the regional level. Given the decision-making process within the federal forest sector this is the appropriate scale for many variables. For example, private timber firms would have operated across districts and federal budgets were allocated to regions. However, having variation at the district level on indicators such as road density, area of timberland leased, or number of forest sector employees should provide additional information about intra-regional heterogeneity. I have asked Russian partners to search for these variables at the district-level and will incorporate these data, even if only available for a subset of regions, into the analyses in this chapter.

In addition to district- and regional-level determinants of harvesting, macroeconomic variables such as export tariffs and timber imports should have affected timber rents. The impact of these variables, however, should have been constant across regions. I will use a dummy variable to capture changes in these temporal effects between 1990 to 2000 and 2000 to 2005. Specifically, data from 1990 to 2000 will be coded as zero and data from 2000 to 2005 will be coded as one.

Table 1. Data Availability

Variable Name	**Description**	**Source**	**Time variation**	**Scale**	**Data Availability**	
					1990-2000	**2000-2005**
Biophysical Variables						
TIMBER	Total forest area (ha)	Remote sensing	Yes	District	X	X
CONIFER	Coniferous forest (ha)	State Registry of the Forest Fund	Yes	Region	X	X
AGE	Mature and overmature forest (ha)	State Registry of the Forest Fund	Yes	Region	X	X
SLOPE	Average slope (degree)	Geographic information systems (GIS)	No	District	X	X
Socioeconomic Variables						
ROAD	Road density (km of road per 1000km^2 of territory)	Goskomstat Rossii	Yes	Region	X	X
DISTANCE	Distance to markets (km)	GIS	No	District	X	X
EMPLOYEE	Forest sector employees (number)	Federal Agency of Forestry	Yes	Region	X	X
ENTERPRISE	Private timber enterprises (number)	Goskomstat Rossii	Yes	Region	X	X
BUDGET	Forestry budget from federal government (%)	Federal Agency of Forestry	Yes	Region	X	X
LEASE	Area of forestland leased (ha)	Federal Agency of Forestry	Yes	Region	X	X

IV. Empirical Approach

<u>Total harvesting</u>

Given data availability and nesting of districts within regions, I will estimate a multilevel linear model for total timber harvested. Multilevel models allow different scales and levels of data to be explicitly incorporated into the regression model. They are most useful for data that have an individual as well as a group aspect, such that there is a natural hierarchical relationship (Snijders and Bosker 1999;

Frees 2004; Cameron and Trivedi 2005). In multilevel analysis, error terms – known as random effects – are included for individual and group effects, capturing unexplained variation within groups and between groups. Explanatory variables can be added to the model at both the individual and group level. Multilevel models can incorporate random intercepts and or random slopes. Thus, the specification of a multilevel model is quite flexible.

To explain the area of timber harvested over time, *t*, I will use a two-level hierarchical model where districts, *j*, are the level-1 individual effects, and regions, *k*, are the level-2 group effects. The level-1 model can be expressed as:

$$HARVEST_{jkt} = \beta_{0k} + \beta_{1k}TIMBER_{jkt} + \beta_{2k}SLOPE_{jk} + \beta_{3k}DISTANCE_{Moscow\ jk} + \beta_{4k}DISTANCE_{St.Petersburg\ jk} + \beta_5 YEAR_t + r_{jk} \tag{11}$$

In Equation 11, r_{jk} is the district-level error term. The time dummy variable mentioned in Section III is estimated by β_5. The β_{0k} term represents the effect common to all districts within the same region; specifying these level-2 effects:

$$\beta_{0k} = \gamma_{00} + \gamma_{01}AGE_{kt} + \gamma_{02}CONIFER_{kt} + \gamma_{03}ROAD_{kt} + \gamma_{04}EMPLOYEE_{kt} + \gamma_{05}ENTERPRISE_{kt} + \gamma_{06}BUDGET_{kt} + \gamma_{07}LEASE_{kt} + \mu_{0k} \tag{12}$$

In Equation 12, γ_{00} is the average outcome for the population and μ_{0k} is the region-specific error term. Substituting Equation 12 into Equation 11 gives:

$$HARVEST_{jkt} = \gamma_{00} + \gamma_{01}AGE_{kt} + \gamma_{02}CONIFER_{kt} + \gamma_{03}ROAD_{kt} + \gamma_{04}EMPLOYEE_{kt} + \gamma_{05}ENTERPRISE_{kt} + \gamma_{06}BUDGET_{kt} + \gamma_{07}LEASE_{kt} + \beta_{1k}TIMBER_{jkt} + \beta_{2k}SLOPE_{jk} + \beta_{3k}DISTANCE_{Moscow\ jk} + \beta_{4k}DISTANCE_{St.Petersburg\ jk} + \beta_5 YEAR_t + \mu_{0k} + r_{jk} \tag{13}$$

This combined model can be estimated using full or restricted maximum likelihood estimation (Frees 2004). In addition to estimates of the slope coefficients, the intraclass correlation coefficient can be estimated from the variance attributable to r_{jk} and μ_{0k}, which will indicate the percent of variation from district- and regional-level characteristics. While the justification for a multilevel model comes from the suspected correlation between districts nested within a region, it is also preferred in this application because data on several variables are not available at the district level. Estimating the multilevel model avoids the problem of assuming that regional data can be assigned equally to all districts, which can lead to underestimation of the standard errors (Overmars and Verburg 2006). Equation 13 can be modified to include interactions between district- and regional-level covariates. In addition, if the effect of a particular covariate is expected to vary across regions, then random slopes can be added.

Multilevel models impose a formal structure on the covariance estimates by including random effects at both the district- and regional-level. This structure allows correlation across districts within a region. To rule out the possibility that spatial correlation is a concern across regional boundaries, I will still estimate the Moran's-I statistic (Anselin 1999). I will also use panel-robust standard errors with clusters at the regional-level to control for all functional forms of serial correlation and heteroscedasticity (Cameron and Trivedi 2005).

The multilevel model can also be affected by endogeneity bias if any unobservables are correlated with the regressors and the dependent variable. This bias can come from unobservables at the district- or regional-level. The district-level variables (Equation 1) can be modeled as exogenous variables. The discussion on endogeneity in Chapter 1 identified two potential endogeneity concerns at the regional level: the number of private timber enterprises and the volume of timber sold in auction. Equation 13 also includes ENTERPRISE and includes a variable similar to volume auctioned – LEASE. As discussed in Chapter 1, regional characteristics such as pro-market preferences and institutional strength may have impacted the number of firms and the use of auctions to allocate timberland, and these characteristics may have also impacted timber harvesting. If the analysis in Chapter 1 finds that regional characteristics did impact firms or auctions, then the inclusion of the region-specific random effect (μ_{0k}) in Equation 13 will introduce a time-invariant spatially-correlated unobservable. Measurement error will also be a concern in Equation 13 since AGE and CONFIER will come from national statistics. Similar to Chapter 1, an instrumental variables approach that uses multiple measures for AGE and CONIFER can be used to correct for errors in measurement (Wooldrige 2009).

If the region-specific error term is included as a random effect, I will use instrumental variables to address these endogeneity concerns. Multilevel instrumental variable estimation techniques have been developed (Spencer and Fielding 2000)and incorporated into a software package for fitting multilevel models known as MLwiN (MLwiN, online). I would use instrumental variables similar to those outlined in Chapter 1. For ENTERPRISE I would use the percent of votes for the pro-reform party in the 1993 legislative elections and or the amount of credit distributed to private enterprises. For LEASE I would use stumpage prices to instrument for the amount of timberland leased. FOR CONIFER and AGE I would use measures of the volume (m^3) of timber to instrument for measures of area (ha). I would also consider using a measure of the average volume of timber harvested in previous years to instrument for CONIFER and AGE; data are reported on the total volume of harvesting in Russia at the regional level from 1946 to 1988 (IIASA Russian Forests & Forestry project, online). Another alternative would be to specify μ_{0k} as a fixed effect.

Forecasting

Using results from Equation 13 I will forecast future harvesting in the study region to 2030. In most forecasting exercises a subset of the data are used to estimate the model (the training set) and another subset of the data (the testing set) are used to validate the forecasts. The accuracy of the forecasts can be tested using the mean absolute error or the mean absolute percentage error between forecasted and actual values in the testing set (Frees 2004). For this analysis, I will use the 1990 to 2000 change data as the training set and the 2000 to 2005 change data as the testing set. If possible, remote sensing data of harvesting activity between 2005 and 2010 for a subset of the study region will be used to validate forecasts.

Forecasting will be complicated somewhat by the introduction of a new Forest Code in 2007 that changed property right arrangements. Specifically, the 2007 Forest Code introduced lease periods of 99 years and transferred responsibilities and costs of replanting from the forest sector to private enterprises (Torniainen 2009). From an economic perspective these institutional changes should improve the efficiency of timber harvesting and shift the optimal time to harvest toward the Faustmann rotation period. While this change in property rights arrangements cannot be included explicitly in the forecasts, the impacts of changes to at least three economic variables can be tested using this framework. First, reductions in informal bribes and fees in the forest sector should lead to more competitive auctions and more timberland leased to private firms. Thus, I will explore how increases in the area of timberland leased would impact future timber harvests. Second, if the number or capacity of timber firms is related to regional implementation of pro-reform policies (this will depend on findings in Chapter 1), then improvements in privatization effectiveness at the regional level should impact firms and thus, future timber harvest rates. Third, the impact on timber harvesting from changes in the amount of federal budget allocated to a region for forestry activities will be explored.

Illegal versus legal harvesting

Remote sensing data of forest disturbance should provide a more accurate estimate of area cleared than the national statistics used in Chapter 1. This is because some timber enterprises were operating within the virtual economy and so transactions for the right to harvest timber, and therefore harvesting, may have gone unreported. There is also evidence that the local FMU supplemented their incomes through “illegal” harvesting (Eikeland et al. 2004). While some of this illegal activity will not be detectable in the remote sensing analysis due to scale (much of the illegal harvesting by local units was selective logging), remotely sensed data should still provide a more accurate detection of clear-cutting activity within the sample area than what is reported in national statistics.

Remote sensing data will be reported in area (ha) whereas national statistics are reported in volume[20] (m^3) and only at the regional level. Despite differences in measurement, I will provide approximations of the area of forest harvested from remote sensing and reported by the government at the regional level and use econometric models to analyze the factors associated with logging classified as unreported or “illegal”. To compare area to volume, I will use information about growth and productivity in Russian forests produced by the International Institute for Applied Systems Analysis and available on their project website “Russian Forests & Forestry” (IIASA, online). This data gives the growth rates (m^3/ha) for different species, age classes, and site indexes (i.e., bonitaet scale) throughout Russia. To compare the two sources of data, several assumptions about age class and stocking levels will have to be made, but even a best approximation at unreported harvest levels should be informative for understanding the transition to a market-based forest sector in Russia. Given the uncertainty in estimates of reported versus unreported logging, I will not try to causally explain illegal logging but provide a description of the types of factors associated with higher levels of unreported harvesting.

To describe factors associated with unreported logging rates I will estimate the following two-way linear effects model for regions, *k*, and time, *t*:

$$HARVEST_{kt} = \alpha_k + YEAR_t + \gamma_1 TIMBER_{kt} + \gamma_2 LEASE_{kt} + \gamma_3 CONIFER_{kt} +$$
$$\gamma_4 AGE_{kt} + \gamma_5 ROAD_{kt} + \gamma_6 EMPLOYEE_{kt} + \gamma_7 ENTERPRISE_{kt} + \gamma_8 BUDGET_{kt} +$$

[20] Government statistics do report the area of dead stands from fire and disease and the area of plots leased (although this does not mean they were cut in that year), making further comparisons possible.

$$\gamma_9 DISTANCE_{Moscow\ k} + \gamma_{10} DISTANCE_{St.Petersburg\ k} + \varepsilon_{kt} \quad (14)$$

Similar to Chapter 1, I will test for fixed effects in this model using the Hausman test. If random effects are the efficient estimator I will instrument for ENTERPRISE and LEASE. Using either fixed or random effects models I will control for measurement error in CONFIER and AREA using values of both volume and area. Panel-robust standard errors will be used to control for serial correlation and heteroscedasticity. I will test for spatial correlation, but if the fixed effects model is used then efficient estimation will be achieved without imposing additional structure on the covariance estimates.

V. Expected Outcomes & Significance

This chapter will produce the first district-level econometric model of forest harvesting decisions in Russia after the collapse of the Soviet Union and the implementation of new institutions. I will develop a conceptual model of timber harvesting in Russia and estimate the drivers of timber harvesting after independence. These drivers will be used to forecast future harvesting rates under alternative forest institutions and economic incentives. I will also calculate the approximate difference in reported and unreported logging rates and provide a description of factors related to illegal logging. The results of this work will be summarized in a journal article for the Journal of Environmental Economics and Management.

B.3. Chapter 3: Biodiversity impacts of land-use change

Research Question: How will future land-use changes impact wildlife habitat around a protected area in Russia?

I. Overview

Land-use change affects ecological, economic and cultural outcomes. In Europe the most widespread land-use change is agricultural abandonment. Abandonment can lead to biodiversity losses, increases in fire frequency, and losses in cultural values (Rey Benayas et al. 2007). Abandonment can also increase biodiversity depending on the habitat niche of the species (Russo 2006). Several recent studies have focused on the impacts of abandonment on biodiversity loss, particularly in the Mediterranean biodiversity hotspot region (Russo 2006; Falcucci et al. 2007; Sirami et al. 2008; Fonderflick et al. 2010). However, most of these papers do not consider the drivers of land abandonment and how future land-use change will alter habitat suitability. Furthermore, none of these previous works consider how land-use change might positively impact biodiversity. In this paper I will develop a spatially-explicit model of land-use change around a protected area in Ryazan region in Russia. Land abandonment is the largest land-use change but forest harvesting is also an important process. I will develop discrete-choice models for both land uses and simulate future landscapes. These future landscapes will be used as inputs into maximum entropy models to predict habitat suitability for three large mammals found within and outside the protected area.

While predicting general trends in land use is possible using district-level data, to inform conservation decisions a spatially-explicit model of land use is needed (Lewis 2009). Using remote sensing data on observed land-use changes at a parcel level, a discrete-choice econometric model can be estimated to determine parcel-scale transition probabilities. These transition probabilities are the decision rules that guide future land-use changes. Lewis and Alig (2009) describe how simulation can be used to generate a large number of different landscapes that conform to the underlying probabilistic transition rules. Simulation methods are an improvement over previous methods that assumed a parcel converted to the land-use with the highest estimated transition probability. Simulations can be summarized according to the goals of a particular study and incorporated into quantitative ecological models of species habitat or environmental flows. This two-step procedure has been used to estimate the impacts of land-use changes on biodiversity in Oregon (Nelson et al. 2008; Lewis et al. 2009), fish populations in California (Lohse et al. 2008), green frogs in Wisconsin (Lewis 2009), and coarse woody debris and bluegills in Wisconsin (Butsic et al. 2010).

In Russia, very little is known about the drivers of land-use change, let alone how these changes impact biodiversity. In Chapters 1 and 2 of this paper I focus on drivers of forest harvesting. I will use this knowledge to develop a discrete-choice model of forest harvesting[21] at the parcel level for several districts within Ryazan region. In addition, I will develop a discrete-choice model for land abandonment. Given differences in decision-makers and land-use transitions, I will estimate separate econometric models for parcels beginning in forest and agriculture (Lubowski et al. 2006; Lewis and Plantinga 2007). I will use my econometric models to simulate landscape changes until 2030. In addition to a business-as-usual scenario I will also incorporate at least one alternative policy scenario. One possible scenario is to consider possible landscape changes if a market for

[21] Forest harvesting constitutes a much smaller percent of land-use change in the area than land abandonment; as more information about the study site and land uses becomes available I may decide only to model land abandonment.

agricultural biofuels emerged in Russia; a research project is currently underway in Russia to assess the potential of using abandoned agricultural land for growing biofuels.[22]

II. Background

Zapovednik Oksky and Ryazan Region

The study site for this research is Zapovednik Oksky and several districts surrounding the protected area (Figure 1). A Zapovednik is the strictest type of protected area in Russia. Zapovednik Oksky is located in the northern part of Ryazan region. Ryazan region is located in the central part of Russia. The economy of the region is a mix of industry and agriculture, with more than 70 percent of industrial production concentrated in the capital city. The region is located in a transitional zone for agriculture with agroclimatic conditions varying from north to south (the south being better suited for agriculture). Grain yields average 1 to 1.5 tons per hectare, which is slightly below the 2 tons per hectare average in Russia's Central Black Earth region (Ioffe et al. 2004). In 1990, agricultural cropland covered about 1,700 thousand ha in Ryazan. Since independence the cultivated area has decreased rapidly – it was about 800 thousand ha by 2005. Approximately 50 to 60 percent of the region is currently under cultivation. Other major changes between 1990 and 2000 included a decrease in: rural population (-10%), meat production (-60%), and grain production (-44%).

Zapovednik Oksky is located along the Oka River. Geographically, the Oka River divides Ryazan region's two biomes: to the north of the river are the mixed forested zones and to the south are the broad-leaved forest and forest-steppe. The protected area was established in 1935 and covers about 55,000 hectares with a core protected zone of 22,700 hectares. Oksky protects many species, including moose, fox, wolf, marten, beaver, and numerous birds of prey. Habitat models for moose, wolf, and wild boar are being developed by Anika Sieber, a PhD student at Humboldt University in Germany[23]. I will collaborate with Anika to input landscape simulations of forest harvesting and agricultural abandonment into habitat models to estimate future species distributions.

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[22] A project assessing biogas potential in European Russia was recently launched by the German Environment Ministry. This project is being led by Daniel Muller, a research scientist who has collaborated with Volker Radeloff's lab at UW-Madison.

[23] Volker Radeloff is a partner on this project and in general, Volker's lab at UW-Madison has a good working relationship with the lab that is carrying out this project at Humboldt University.

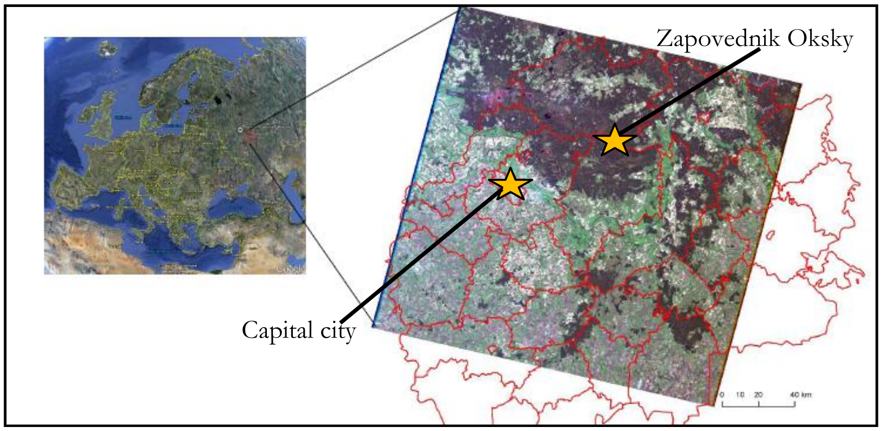

Figure 3. Ryazan region land-use classification extent and Zapovednik Oksky
Source: Anika Sieber

Moose (*Alces alces*) live primarily in forested areas, and depend on woody species and shrubs for forage. While moose populations had declined in Russia over the 19th and 20th centuries, their population density today is stable (Baskin and Danell 2003). Moose populations ranged from less than a hundred to around 400 in Oksky over the last ten years (Seiber, presentation). Wild boars (*Sus scrofa*) are eurytopic, using shrubs, tall grass or dense forest stands for shelter. Wild boars are omnivores and eat in fields or shrub layers or forage below ground (Baskin and Danell 2003). There are about 400 wild boars in Oksky; this number fluctuated between 200 and 800 over the last decade (Seiber, presentation). The third species is a predator of moose and wild boar – the Russian Wolf (*Canis lupus communis*). Russian wolf are dependent on population levels of the other two species. There were approximately 10 wolves observed in Oksky over the last decade (Seiber, presentation). In the habitat models for these species, Anika will use variables on forest type, forest fragmentation (e.g., core forest, edges), forest succession, and agricultural abandonment.

Of the species being studied, moose are the most sensitive to land-cover change. Moose are primarily a forest species and favor mature forests far from human settlements for habitat. These dense forests provide sufficient refuge from weather extremes. Within a home range, moose respond to food quantity and prefer to graze on early succession vegetation (Nikula et al. 2004). In particular, moose tend to graze in open areas following disturbance such as wind or fire. Since moose prefer young vegetation, especially pine-dominated growth, intensive forestry practices such as clear-cutting have been associated with moose abundance. This has created tensions between forestry practices and moose management in the Nordic countries (Lavsund et al. 2003). In general, moose require a diverse mosaic of mature forest and open areas. Land-use changes around

Zapovednik Oksky, especially the abandonment of agricultural lands, may provide moose with additional forage opportunities and chances to extend its range outside of the protected area.

Land Abandonment

Mapping of land abandonment in one agro-climatic zone of European Russia found that 37 percent of agricultural land was abandoned between 1989 and 2000 (Prishchepov et al., unpublished). The rate of abandonment was greater than 50 percent for some regions. High rates of intra-regional variation and lower abandonment around major cities was also observed. Land abandonment rates in Ryazan region follow a similar pattern, with lower rates of abandonment around the capital city between 1989 and 2000 (Figure 2). Abandonment rates around Zapovednik Oksky were higher, ranging between 24 to 45 percent.

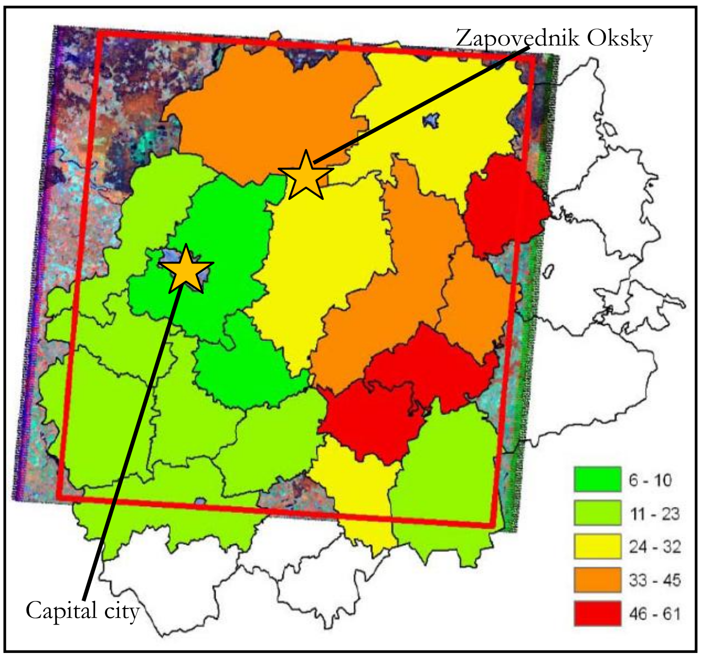

Figure 4. Land abandonment rates in Ryazan region
Source: Alexander Prishchepov

These estimates of land abandonment illustrate that large changes were occurring in Russia after independence. Studies from other former Soviet countries can provide information about potential drivers of land abandonment in Russia, as can meta-analyses. Rey Benayas et al. (2007) conducted a descriptive meta-analysis of 45 studies on land abandonment. The socioeconomic drivers identified as important in these studies included market incentives, migration and rural depopulation, market access, and land-tenure systems and security. Biophysical drivers identified in this meta-analysis included elevation, slope, soil fertility, and climate. The authors concluded that socioeconomic drivers played a larger role than biophysical factors in the decision to abandon agricultural land since they were identified in more than 30 of the reviewed articles whereas biophysical factors were only mentioned in ten.

Turning to former Soviet countries, Muller and Munroe (2008) estimate a parcel-level model of cropland abandonment and forest cover loss for four districts in Albania from 1988 to 2003. They focus on the institutional effects that occurred when Albania transitioned from collectivism to privatization and the impacts this had on land-use practices. They combine data from household surveys and plot-level information for the land abandonment model. Model covariates include biophysical factors such as slope, elevation, rainfall, and soil suitability. Socioeconomic covariates include distance to roads and settlements, a proxy for costs of transport to district capital, population density, remittances, a proxy for land fragmentation, education, irrigated area, and number of tractors. Few variables from the household survey were statistically significant in the model. The authors conclude that cropland abandonment was concentrated in marginal, less densely populated areas and that market returns from nonfarm activities contributed to increased abandonment. Slope and elevation were also statistically significant in their regression models.

Lakes et al. (2008) look at cropland abandonment in Romania from 1995 to 2004. They consider one district within Romania that was subdivided into 99 communes – the lowest level of administrative subdivision in the country. Commune-level data was collected on population, crop yield, number of livestock, and number of people employed in agriculture and education. They also include biophysical data on elevation, slope and range of slope, as well as measures of distance of a commune to road networks and markets, and the density of cropland, forest, grassland and settlements at the start of the time period. Using logistic regression they find higher abandonment rates associated with higher elevations, steeper slopes, and further distance to roads. They also find that the spatial pattern of land use mattered, with less abandonment on parcels surrounded by existing cropland or settlements. Finally, they find that areas with more livestock had lower rates of abandonment.

Finally, a recent paper by Baumann et al. (2010) focuses on land abandonment in three regions in Western Ukraine from the late 1980s to 2008. Linear regression models were applied to explain district-level abandonment rates. Four types of explanatory variables are used as covariates: environmental variables, access variables, population variables, and land use practices. Specifically, environmental or ecological factors include slope, elevation, soil type, and an agricultural suitability index. Socioeconomic variables include distances to roads and markets, population density, village density, number of tractors, number of farm employees, and unemployment rates. The most important explanatory variables in the regression models included soil type, population changes, village density, and elevation. However, unlike previous studies, the authors find lower abandonment rates on steep slopes and other marginal areas which they argue reflect subsistence-based agricultural patterns in Western Ukraine.

III. Conceptual Framework

Under a competitive market, a decision-maker is expected to allocate a homogenous land parcel to the use that maximizes rents. This is the optimal allocation rule assuming decision-makers have static expectations about their net returns and costs (Plantinga 1996).Thus for parcel, *i*, at time *t* :

$$max_{it} R_{it} = P_{it} * Q_{it} - W_{it} * I_{it}, \tag{1}$$

where:

P_{it} = output prices

Q_{it} = quantity

W_{it} = input costs

I_{it} = inputs

In forestry, similar to Chapter 2, timber will be cut if:

$$R_{it,cleared} > R_{it,uncleared} \tag{2}$$

However, for land abandonment, the decision is to minimize farm losses; thus, the decision-maker stops farming if:

$$R_{it,cultivated} < R_{it,uncultivated} \tag{3}$$

The rents obtained from these land uses will depend on the observable and unobservable characteristics of *i* at time *t*, which can be expressed as:

$$R_{it} = \alpha + \beta X_{it} + \varepsilon_{it}, \tag{4}$$

where:

$$\alpha = constant$$

$$\beta = vector\ of\ coefficients\ to\ be\ estimated$$

$$X_{it} = vector\ of\ covariates$$

$$\varepsilon_{it} = random\ distrubance\ term$$

We cannot observe R_{it} directly but only observe whether a parcel of land is cut or abandoned; we motivate this binary choice as a latent response variable. For forest harvesting the choice observed can be indicated as R_{it}^* and takes on the following values:

$$R_{it}^* = \begin{cases} 1 \; if \; R_{it} > 0 \\ 0 \text{ otherwise} \end{cases} \tag{5}$$

Land abandonment would follow the same logic except that the greater than sign would become a less than sign.

To empirically estimate Equation 4 the distribution function for the error term must be chosen. For many binary decision models either a logit or probit model is used (Train 2009). The logistic distribution function is:

$$P(R_{it}^* = 1) = \frac{\exp(\alpha + \beta X_{it})}{1 + \exp(\alpha + \beta X_{it})} \tag{6}$$

The probit model is based on the cumulative distribution function of the standard normal:

$$P(R_{it}^* = 1) = \Phi(\alpha + \beta X_{it}) \tag{7}$$

IV. Data

Remote sensing will be used to classify forest harvesting and land abandonment for two time periods: 1989 to 2000 and 2001 to 2008. Within the Landsat footprint (Figure 1) parcel-level information on land-use change will be recorded. The smallest resolution is a 30x30 meter grid but this unit can be aggregated to larger grids depending on the sampling unit of interest. I will assess tradeoffs between scale, sample size, and the conservation objectives of this study to determine the appropriate grid size to use. To avoid underestimation of coefficients by including all parcels in the analysis, only areas that were cropland at the start of the change periods (i.e., 1989 and 2001) will be included in the model of land abandonment. If agricultural land is abandoned over a time period it will be coded with a one, otherwise it will be coded as a zero. A similar strategy will be applied for timber harvesting: only parcels that were forested at the start of the change period will be included and if the parcel is cut it will receive a one.

Independent variables will come primarily from the parcel and district level, but if possible, municipal-level data will be included. Municipalities are the smallest administrative unit in Russia and form the boundaries of urban and rural settlements within districts. Municipal data may be available on population density and other socioeconomic variables, but I have not identified whether I can procure this data for this project, and so I focus on district- and parcel-level data for the remainder of the proposal. District-level data will include information on: agricultural yields, livestock numbers, population density, number of farms and average farm plot size. Parcel level-data will include information on: forest area and type, slope, elevation, and distance to markets.

In the econometric model of forest harvesting I will use parcel-level measures of slope, elevation, and forest area (Table 1). If possible, I will also collect district-level data on the number of forest sector employees, the amount of timberland leased and road density. Many of the variables identified in Chapter 2 only varied at the regional level and will apply to all parcels in this analysis. For the land abandonment model independent data will consist of similar parcel-level measures of slope, elevation, and distance to markets. An additional parcel-level variable will be the distance of parcels to municipalities. While data on soil quality, precipitation and degree days were used in the studies of land abandonment discussed above, it is not clear whether this type of information would vary considerably over the sample area and or whether this type of data is available. District-level data will be used on: population density, crop yield, number of livestock, average farm size and number of farms. Ideally, data on farm tenure will also be collected for this study, but I have not identified whether information on farm type (e.g., household plot, peasant farms or corporate farms) is available at the district level or not.

Table 1. Data Availability

Variable Description	**Source**	**Scale**	**Time Variation**	**Land-use model**	
				Forest harvesting	**Land abandonment**
Data available					
Total forest area (ha)	Remote sensing	Parcel	Yes	X	
Coniferous forest (ha)	Remote sensing	Parcel	Yes	X	
Average slope (degree)	Geographic information systems (GIS)	Parcel	No	X	X
Average elevation	GIS	Parcel	No	X	X
Distance to capital city (km)	GIS	Parcel	No	X	X
Distance to municipalities (km)	GIS	Parcel	No		X
Rural population density (people per km^2)	National statistics	District	Yes		X
Sown grain (thousand ha)	National statistics	District	Yes		X
Grain yields	National statistics	District	Yes		X

(tons/ha)					
Livestock yield (liters/cow)	National statistics	District	Yes		X
Average farm size (km^2)	National statistics	District	Yes		X
Number of farms	National statistics	District	Yes		X
Data not yet available					
Number of forest sector employees	Federal Agency of Forestry	District	Yes	X	
Area of timberland leased	Federal Agency of Forestry	District	Yes	X	
Road density (km^2)	National statistics	District	Yes	X	X
Land tenure (farm ownership)	National statistics	District	Yes		X

V. Empirical Approach

Econometric Analysis

Forest harvesting

The purpose of the econometric models will be to identify the parcel- and district-level variables that are associated with previous forest harvesting and land abandonment decisions. Discrete-choice models can be estimated under a variety of distributional specifications and assumptions; the two most common binary choice models are the logit and probit (Train 2009). Maximum likelihood techniques are used to estimate model parameters in both the logit and probit models. Below, I will present econometric specifications using the probit model, where $\Phi(.)$ denotes the standard normal cumulative distribution function; however, a logit model could also be used.

In Equation 5, if the net value from cutting a forested parcel in district, *j*, is positive then let $f_{ijt} = 1$. The probability that f_{ijt} will be cut is given by:

$$\Pr\left(f_{ijt} = 1 \middle| x_{ij}, z_{ijt}, q_{jt}, r_t, \alpha_j, \mu_i\right) = \Phi(\beta x_{ij} + \gamma z_{ijt} + \delta q_{jt} + \zeta r_t + \alpha_j + \mu_i + \varepsilon_{ijt}) \qquad (8)$$

Where, x_{ij} are the time-invariant parcel-level variables identified in Table 1, z_{ijt} are the time-variant parcel-level variables, q_{jt} are the time-variant district-level variables, r_t is a time-specific dummy variable, α_j are a set of district-specific effects, μ_i are parcel-specific effects, and ε_{ijt} is an independently and identically distributed (IID) standard normal random variable.

In non-linear panel models μ_i is typically modeled as an IID normal random effect due to computational restrictions (Cameron and Trivedi 2005). Including μ_i as a random effect means that endogeneity bias will be a concern if any of the explanatory variables are correlated with the random effect. In Equation 8, none of the parcel-level variables should pose an endogeneity concern. Measures of slope, elevation and distance to markets are time invariant and best modeled as exogenous. Measures of original timber area and area of coniferous forest will come from remote sensing estimates. There are no foreseen unobservables between these biophysical attributes of the parcel and the random effect.

If α_j are included as random effects then unbiased estimation requires that none of the explanatory variables are correlated with the district-level random effects. In Equation 8, q_{jt} variables have not been obtained. If information on forest sector employees, road density and area of forest leased is obtained, there could be district-level unobservables correlated with the area of forest leased. Recent modeling techniques such as the Mundlak-Chamerblain device relax the standard assumptions of the random effects model within the discrete-choice model and can thus be used in models with endogeneity concerns (Cameron and Trivedi 2005; Lewis et al. 2010). Another option would be to specify μ_i as random effects but α_j as fixed effects using a dummy variable structure. Cluster fixed effects can be estimated in the binary logit model if the number of clusters is small relative to the number of observations, which is the case in this analysis (Cameron and Trivedi 2005).

Since I expect decisions across parcels within the same district to be correlated, I will use cluster-robust standard errors to control for spatial correlation within districts. The inclusion of fixed neighborhood effects has emerged as an alternative to distance-based weight matrices to control for spatial correlation (Anselin 2002; Cameron and Trivedi 2005; Gellrich et al. 2007; Muller and Munroe 2008; Horsch and Lewis 2009). Cluster-robust standard errors also control for all functional forms of serial correlation and heteroscedasticity. Cluster-adjustment does not impose a formal structure on the model and so does not affect coefficient estimations.

Land Abandonment

For land abandonment, if the net value from cultivating an agricultural parcel in district, *j*, is negative then let $l_{ijt} = 1$. The probability that l_{ijt} will be abandoned is given by:

$$\Pr\left(l_{ijt} = 1 \middle| x_{ij}, q_{jt}, r_t, \alpha_j, \mu_i\right) = \Phi(\beta x_{ij} + \delta q_{jt} + \zeta r_t + \alpha_j + \mu_i + \varepsilon_{ijt}) \qquad (9)$$

Where, x_{ij} are the time-invariant parcel-level variables identified in Table 1, q_{jt} are the time-variant district-level variables, r_t is a time-specific dummy variable, α_j are a set of district-specific effects, μ_i are parcel-specific effects, and ε_{ijt} is an IID standard normal random variable. I will use cluster-robust standard errors in Equation 9, clustered at the district level, to control for spatial correlation within a district and to control for serial correlation and heteroscedasticity.

Similar to the discussion about Equation 8, including μ_i as a random effect means that endogeneity bias will be a concern. However, there is no foreseen correlation between the time-invariant parcel-level variables and the parcel-specific effects. If α_j are included as random effects then unbiased estimation requires that none of the explanatory variables are correlated with the district-level random effect. In Equation 9, q_{jt} variables are primarily agricultural and farm characteristics and there may be district-level unobservables correlated with variables such as average farm size or rural population density. To control for this endogeneity additional information could be added to the model to account for the agricultural suitability of a district; this might include information on soil quality or climate. However, if the unobservables of concern are district-level variables such as agricultural or farm policies, then instruments would be needed or q_{jt} would need to be specified as fixed effects in Equation 9.

Forecasting

Results from Equations 8 and 9 will be used to simulate future landscape values. Discrete-choice models give predicted values between zero and one. These are the choice probabilities. Previous land-use studies used these transition probabilities deterministically, assuming that a parcel would convert to the use with the highest estimated probability (for example, if the transition probability was 0.6 it would go into the land use value assigned a one in the regression model). Lewis (2009) describes an alternative method of translating choice probabilities into landscape-change values. This involves using simulation methods to estimate a large number of landscapes that conform to the underlying probabilistic rules. This allows the multiple sources of variation from the model to be captured and is more consistent with the underlying econometric specification of discrete-choice methods.

I will follow the method outlined in Lewis (2009) to simulate landscape effects from the two empirical models in this study. Specifically, I will use the probabilities of forest harvesting and land abandonment and take random draws from the distributions to simulate a number of different landscapes for Ryazan region. If the probability that a parcel will convert is 0.1, that parcel will convert 10 percent of the time if the simulation is repeated enough times (Lewis 2009). These simulated values can then be summarized using moments applicable to the study. In Lewis (2009), 1,000 simulations are used and predictions are made for twenty years. I will summarize the simulated landscapes in this study by mean and standard deviation for each parcel in the study area. This will assign a spatially-explicit value for all land parcels in forest or agriculture at the start of the study period – forested land will have a conversion probability and agricultural land will have an abandonment probability. This will serve as a business-as-usual scenario for future forest harvesting and land abandonment in the study region.

In addition to the business-as-usual model, I will also generate at least one alternative policy scenario for future land abandonment. I will only focus on land abandonment because it is the main land-use change around Oksky. One possible scenario is to estimate the probability of land abandonment if a biogas market emerged in Russia. Many countries in Western Europe are interested in expanding their biomass energy use. A recent announcement by the German government stated that by 2020 it will consume at least 30 percent renewable energies. Researchers at Humboldt University in Germany have started a research project to evaluate the potential for using abandoned farmland in Russia, Ukraine and Belarus to supply biogas markets. Building on existing collaborations between UW-Madison and Humboldt University, I will work with these researchers to develop an index of abandoned farmland suitable for biogas in Ryazan. Using this index I will generate simulations of future land-use based on assumptions about which land parcels would not be abandoned and or would be converted back to agriculture if a biogas market emerged. Similar to the business-as-usual scenario I will summarize simulated landscapes for each parcel by their mean and standard deviation.

To assess the accuracy of predictions under these two scenarios I will use the 1989 to 2000 change analysis as the training set and the 2001 to 2008 change analysis as the testing set. I will assess accuracy based on how well the predicted values correspond to the testing set. Specifically I will calculate the AUC value – the area under the receiver operating characteristics (ROC) curve. A ROC curve provides a graph of the true positives and false positives for a binary system. AUC provides a value between zero and one that indicates similarity between observed and predicted values (a one indicates high similarity).

Coupled Economic-Ecological Model

One of the advantages of creating a spatially explicit simulation of land-use change is that it can inform many important conservation problems (Lewis 2009). In the final component of this research I will incorporate the summarized landscape values under the business-as-usual and alternative land use scenario into habitat models to assess biodiversity conservation impacts. The effects of land abandonment on biodiversity are complex. Agricultural land abandonment can lead to both a decrease in biodiversity and an increase in biodiversity and wilderness (Russo 2006; Rey Benayas et al 2007). The difference depends on the habitat niche of the species. Most published literature has focused on decreases in farmland diversity. Changes in vegetation type after abandonment led to species turnover and shifts in relative abundance and diversity throughout Europe (Russo 2006). In many parts of Europe, humans have maintained farmland for centuries. Thus, many species that live in open habitats or are ecotone specialists have been harmed by recent abandonment of farmlands. In particular, several ecological analyses of the impacts of abandonment in the Mediterranean biodiversity hotspot have found increased abundance of shrubland and woodland species but decreased abundance of traditional Mediterranean-type species (Falcucci et al. 2007; Fonderflick et al. 2010). A meta-analysis found strong increases in shrubland and woodland species but no overall change in occurrence patterns for farmland species (Sirami et al. 2008).

The study site for this research project – Zapovednik Oksky – is located in the coniferous-broadleaf forest zone. Thus, increases in forest cover are expected to increase habitat suitability for most species located within the reserve, with the potential of creating corridors between protected areas. Habitat models being developed by Humboldt University will predict suitability for moose, wild boar and wolf. MAXENT, a statistical model based on the principle of maximum entropy, will be used to model habitat use. MAXENT is a relatively new modeling approach and has been used in quantitative ecology to model species geographic distributions based on presence-only data. MAXENT has been compared to other modeling approaches used in ecological modeling and is generally the more robust model (Philips et al. 2006). The dependent variable in MAXENT can be a discrete or continuous measure of species presence. Explanatory variables used in the model are called "features" and are chosen by the researcher. Features can be continuous or discrete. The output from MAXENT is the likelihood of species presence based on a logistic probability estimate between zero and one. To combine my simulated landscape values to these ecological models a quantitative link between land use and species habitat is needed. MAXENT models typically include spatially-explicit values of vegetative cover. Thus, habitat suitability predictions will be made using simulated vegetative cover under the business-as-usual and alternative scenarios from this research.

VI. Expected Outcomes & Significance

This research will be the first effort to link future land-use changes in Russia with biodiversity impacts. The expected outcomes of this research are estimated parcel-level transition probabilities for forest harvesting and land abandonment in Ryazan region; simulated landscapes in the study region under at least two scenarios; and habitat suitability predictions for three wildlife species under different scenarios. This research will provide the first analysis of land-use change impacts on biodiversity in Russia and will inform the broader literature about the linkages between land abandonment and biodiversity. In addition, this work will provide one of the first empirical models of land abandonment decisions in Russia. Finally, this work will contribute to the relatively new branch of literature that uses simulation methods to integrate economic and ecological models for conservation planning. The results of this research will be targeted at the American Journal of Agricultural Economics. An article focusing on the biodiversity impacts will be developed in collaboration with Anika and targeted at Conservation Biology.

C. CONCLUSION

I. Overall Significance

As outlined in Part A, this dissertation project draws on theories and methods from institutional analysis and land change science. These fields are interdisciplinary and resource economists play a key role in both. In this dissertation project, I will use theory and methods from both fields to understand what drives land-use decisions under new institutional arrangements. This dissertation project focuses specifically on the temperate and mixed forests of European Russia, a region that is important domestically and globally as a source of environmental resources and services. Just as important, this region recently underwent an unprecedented change in resource governance and institutions and little is known about the impacts of these changes on current land management or the implications for future management. This dissertation project will improve understanding on resource outcomes at multiple scales for a large area in European Russia over a period of at least fifteen years. This information will be informative for understanding past resource outcomes and decision-processes in Russia and for informing future policy decisions.

In addition to impacts for Russia, this research project will make broad theoretical, empirical and methodological contributions. Theoretically, it will provide a detailed understanding of the transition pathway when a country implements a market-based system for resource management. In particular, it will consider the external factors that affected transition to a competitive market and the allocation of property rights and the subsequent impacts on economic and ecological outcomes. Preliminary results from this research project show that while transition to a competitive market economy has been slow, the implementation of price signals and use of the auction mechanism has increased over time. Literature suggests that privatization effectiveness was impacted by weak institutions and strong social norms at the regional level (see for example: Berkowitz and DeJong

2003, 2008; Ickes and Ofer 2006; Brown et al. 2009). This study will explore the influence of these types of external factors on the evolution of timber firms and use of auctions. Thus, this research will critically analyze how interactions between economic and political forces and cultural norms can shape adaptation to and implementation of market-based institutions. This type of knowledge will have theoretical implications for a range of market-based approaches to resource management in other transitional and developing economies.

Empirically, this research project will generate several unique analyses of land-use change decisions in European Russia. For forestry, I will specify and test models of decision-making at the regional, district and parcel level. This will provide information on the drivers of timber harvesting and information about how forest managers and timber industries reacted when faced with new resource institutions. This empirical analysis of forests will also provide information about the scale of decision-making, evaluating the significance of and variation explained by factors at different administrative levels. These empirical models are important for Russia and will also inform the broader discipline of land change science. For land abandonment, I will specify and test a parcel-level model of land abandonment decisions. This will be one of the first analyses of abandonment in Russia and thus will inform understanding about this decision process. Similar to forests, these models should have broader impacts by informing the field of land change science. In addition to empirical work on past and current land use, I will provide forecasts of timber harvesting at the district level for the entire study region and forecasts of land abandonment and timber harvesting at the parcel level for one region. Forecasts of timber harvesting at the district level will inform forest management objectives in Russia and will have broader economic implications given the importance of Russian timber on global markets. Forecasts of land use in the Ryazan oblast will inform economic and biodiversity outcomes and tradeoffs from future land management decisions.

Lastly, this dissertation project will provide several methodological contributions. First, I will use a panel dataset to explore spatial and temporal patterns after institutional change in Russia. Both within Russia and in the broader field of institutional analysis very few studies have included the spatial and temporal variation found in this research project. The quality of information about the transition pathway is thus unique. Second, this research will use innovative methods to control for spatial correlation in the econometric analyses. Specifically, I will use multilevel models in Chapter 2 to account for the nested hierarchical structure of decision-making in the Russian forest sector. Multilevel models have only been used by a handful of land change science studies. For parcel-level analysis in Chapter 3, where decisions are not nested but parcels of land are influenced by higher administrative units, I will use a robust estimator (cluster-robust or panel-robust standard errors) to account for the structure of spatial dependence. Accounting for spatial dependence based on fixed neighborhood effects has only recently emerged in spatial econometrics (Anselin 2002). Third, I will combine simulation results from econometric estimation with quantitative ecological models. Linking economic and ecological models to inform conservation planning is still rare, and many previous studies have not accounted for the probabilistic nature of predictions estimated with discrete-choice models. Following methods developed by Lewis (2009) I will generate landscape simulations that account for the full range of variation in land-use predictions and incorporate these results into habitat suitability models for key wildlife species around a Russian protected area. Of additional interest is the coupling of econometric simulations with a maximum entropy model for wildlife habitat. Maximum entropy models are widely used in species modeling (Philips et al. 2006); developing methods to incorporate economic forecasts into these models is thus important for conservation planning.

Appendix

Appendix A. Timeline

	Spring 2010	**Summer 2010**	**Fall 2010**	**Winter 2010**	**Spring 2011**	**Summer 2011**	**Fall 2011**
Chapter 1							
Data collection & organization	X	X					
Empirical analysis		X					
Paper writing		X	X				
Submit to journal			X				
Chapter 2							
Data collection & organization		X	X				
Empirical analysis			X	X			
Paper writing				X	X		
Submit to journal					X		
Chapter 3							
Data collection & organization				X	X		
Empirical analysis					X	X	
Paper writing						X	X
Submit to journal							X

Appendix B. Conference and Paper Targets

Chapter	Conference	Journal
Chapter 1	▪ NASA Land-Cover and Land-Use Change Program Science Team Meeting – Spring 2010 ▪ Society for Conservation Biology – Summer 2010 ▪ International Association for the Study of the Commons – Fall 2010	▪ Eurasian Geography and Economics
Chapter 2	▪ Association of Environmental and Resource Economics Conference – Summer 2011	▪ Journal of Environmental Economics and Management
Chapter 3	▪ Society for Conservation Biology – Summer 2011	▪ American Journal of Agricultural Economics ▪ Conservation Biology

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