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Herd Growth, Farm Organisation and Subsidies in the Dairy Sector of Russia and Kazakhstan

Martin Petrick  and Linde Götz¹ 

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Abstract

Initially taken as a template for farm restructuring after the demise of collective agriculture, the 'Western family farm model' has taken root in the former Soviet countries only belatedly and incompletely. We examine dairy structures in Russia and Kazakhstan and analyse the drivers of recent herd growth. We are specifically interested in the role of farm management and organisation, vertical integration, and the role of policy. Regression analysis based on a sample of 180 randomly selected commercial dairy farms, using an innovative simultaneous equation framework, shows that better herd management and access to milk marketing contracts were more effective in stimulating herd growth than current subsidy payments. We do not find evidence that milking plants belonging to corporate entities or even supra-regional agroholdings grow more substantially than medium-sized individual farms. Twenty-five years after the end of central planning, structural change among commercial dairy farms in Russia and Kazakhstan appears similar in many ways to the patterns observed in the West more recently: smaller farms catch up in terms of herd growth and classical family-run operations coexist with or even emulate vertically integrated agribusinesses based on hired labour. In moving toward this 'new normal' of farming structures, commercial dairy farms in Russia may even be a few steps ahead of their Western counterparts. At the same time, the still sizeable but stagnating group of subsistence producers in rural households finds no equivalent in the West.

Keywords: Dairy farming; herd growth; transitional agriculture; vertical coordination.

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JEL classifications: O13, P23, Q12, Q18.

1. Introduction

After the historical collapse of collectivised agriculture in the former Soviet Union, many observers assumed that emerging farming structures would quickly mimic the ‘Western family farm model’ of middle-sized farms under family ownership and operation, and argued that this was the most efficient model to follow (Lerman, 1998; Sarris *et al.*, 1999). Actual reform outcomes quickly showed that such a swift transition would not happen, and that corporate farm structures would continue to dominate the sector for a considerable time to come (Swinnen and Rozelle, 2006; Petrick and Carter, 2009).

Twenty years later, the Western family farm model has itself come under pressure. Farm consolidation and exits proceed at unabated pace (Zimmermann and Heckeley, 2012; Henley, 2014). Farmers increasingly employ hired workers and managers, operate fields or livestock herds at several locations, rely on outside service providers, and integrate into the value chain (Sumner, 2014). In some European regions, non-agricultural investors have created supra-regional holding structures (such as in East Germany, Tietz *et al.*, 2013) and ‘biological manufacturing’ has become a catch phrase for the industrialisation of agricultural production in the US (Boehlje and Gray, 2009).

Focusing on the dairy sector, our aim is to examine farm structures in two former Soviet countries, the Russian Federation and the Republic of Kazakhstan, and analyse the drivers of recent farm growth. We are specifically interested in the role of internal farm management practices and organisation, vertical integration and the role of policy. In studying these growth factors, we hope to not only provide insights into recent developments in these countries, but also contribute to the wider debates about farm consolidation and structural change at a global scale.

While management and organisational challenges may be increasingly similar to the West, the policy context in the former Soviet countries differs in important ways. Dairy policy in the EU and North America was often designed to buffer the consequences of overproduction and limit expansion. To the contrary, especially in Russia and Kazakhstan, governments aspire to re-invigorate the dairy and meat production capacities following the collapse of former collective livestock herds during the 1990s (OECD, 2013, 2017).

Given the political significance of dairy revival in both Russia and Kazakhstan, and the amount of public funds spent, it is surprising how little analytical work on the economics of dairy farming and policy in these countries is available. While governments in both countries may not encourage independent evaluation of policy measures for political reasons, the lack of sufficiently disaggregated data also hampers deeper investigation. As a result, analysts used to have no other choice than to rely on data published by the national statistical offices.² We take a first step to overcome this

²Even though statistical offices in both countries liberalised their data access policies and revamped their official websites over the past years, the reliability of agricultural production data has occasionally been called into question. Critics assert that cattle stocks and milk production among small producers have been overstated by official statistics, as the informality and small scale of the producers makes them notoriously difficult to measure. Moreover, officials may have an incentive to exaggerate the numbers as they provide a basis for subsidy allocations (Agra-Europe, 2016; USDA, 2016). Wegren (2011, 2015) is one of the few academic analysts drawing on original survey data.

constraint by using primary survey data collected from 180 randomly selected dairy producers in five Russian and one Kazakhstani province in fall 2015.

Specifically, we analyse the determinants of dairy herd growth among commercial farmers, focusing on three sets of factors: (a) producer characteristics such as farm type, size and management, (b) vertical coordination, in particular with regard to consumers and processors, and (c) government subsidies. Building on work by Weiss (1999) and Foltz (2004), we frame this analysis in the international literature on structural change in the dairy sector. Moreover, we connect to debates on agricultural restructuring in post-socialist countries (Sarris *et al.*, 1999; Rizov and Mathijs, 2003; Wegren, 2011).

In addition to providing unique insights into current patterns of dairy farming in Russia and Kazakhstan, we make systematic contributions to the study of farm growth. In the framework of an innovative simultaneous equation regression framework that allows for censored dependent variables (Roodman, 2011), we isolate the factors that determine herd expansion and subsidy absorption. The estimation results allow us to predict an equilibrium herd size and to quantify the major driving forces of herd growth. By empirically demonstrating how on-farm management practices and marketing arrangements stimulate or retard growth, we add to the emerging literature on value chain modernisation in transitional agriculture (Dries *et al.*, 2009; Sauer *et al.*, 2012). Finally, this paper is among the first to empirically evaluate the success of policy measures aiming at import substitution in Russia and Kazakhstan. We scrutinise the effectiveness of these measures and discuss plausible alternatives.

After a review of post-socialist dairy restructuring in section 2, we discuss the data and various definitions of herd growth in section 3 and introduce our econometric approach and hypotheses in section 4. Section 5 presents regression results on the determinants of herd growth. Section 6 discusses these findings more deeply and section 7 concludes with implications and policy recommendations. Complementary figures and tables are included in Appendices S1–S2 to the paper.

2. Post-Soviet Dairy Chain Restructuring in Russia and Kazakhstan

2.1. *The issue of domestic self sufficiency*

Central planning of livestock production during the Soviet Union had favoured the establishment of industrialised dairy complexes hosting a thousand cows plus, with the aim of achieving regional self-sufficiency all across the Union. Fodder was transported over large distances at no cost to the farms if the local supply base was insufficient (Dronin and Bellinger, 2005, chapter 9). In parallel, rural households were given the right to keep some cattle for own consumption and supply to the local market (Wegren, 2015). After the breakdown of socialism, the elimination of subsidies, sharp rises in feed prices, and a declining demand due to plummeting real consumer incomes led to a widespread collapse of the livestock herds of the former state and collective farms (Bjornlund *et al.*, 2002). Cattle stocks in commercial operations have hardly recovered since, in either Russia or Kazakhstan (OECD, 2013; Petrick, 2014), whereas subsistence farming in households has continued or even expanded in the early years of transition (Petrick and Oshakbaev, 2015).

Against this background and as a reaction to sanctions by Western countries in the course of the political conflict over Ukraine, the Russian government imposed an embargo on a range of agricultural and food products imported from the European

Union (EU), the United States, Canada, Australia and Norway in August 2014 (FAO, 2014). As worldwide food prices had increased and droughts in some of the main agricultural regions had occurred, self-sufficiency in food became (again) a strategic policy goal of the Russian government (Wegren *et al.*, 2016). Among all products covered by the Russian import ban, the deficit in domestic self-sufficiency has been large for dairy products. During the past years, about 20% of domestic consumption in Russia has been met by imports (Figure S1, Appendix S1, left panel). Moreover, other than in poultry or pork, self-sufficiency has not caught up recently (Gataulina *et al.*, 2016; Götz and Jaghdani, 2017; Sedik *et al.*, 2018).

Potential exporters not affected by the ban were keen on replenishing the shelves of Russian retailers, in particular from neighbouring Belarus and Kazakhstan, which are members of the customs union within the Russian-led Eurasian Economic Union (EAEU). However, while Belarus strengthened its position as the major exporter of dairy products to Russia, Kazakhstan struggles to meet its own self-sufficiency targets, as about 10% of consumption continues to depend on imports (Figure S1, Appendix S1, right panel).

2.2. Outcomes of recent farm restructuring

Whereas the majority of dairy cows are based in rural households in Kazakhstan today, a polarised herd structure has prevailed in Russia (Figure S2, Appendix S2; Petrick and Oshakbaev, 2015). It consists of restructured former collective farms now generally in a corporate legal form as agricultural enterprises on the one hand, and rural households on the other. Continuing the Soviet tradition of subsistence farming, household producers are typically much smaller than Western-type family farms. While output growth occurred on household farms in the 1990s, it has levelled off recently. Most observers agree that household producers react only inelastically to a change in their economic environment (Pallot and Nefedova, 2007, p. 200; Wegren, 2015).

After many years of stagnation, individual farmers have recently emerged as a third type of dairy producer different from enterprises and households (Figure S2, Appendix S2; Wegren, 2011).³ This farm type arose as a new legal form during land privatisation in the 1990s. In Russia, individual farmers are entrepreneurs who own (some of) the land and assets they operate. Individual farms in Kazakhstan are mostly registered 'peasant' farms which operate public land under long-term lease from the government. For the past 15 years, individual farmers have been the only category of dairy producers with positive aggregate herd growth in Russia, and in Kazakhstan their aggregate herd size is much bigger than that of enterprises (Figure S2, Appendix S2).

Whereas individual farms displayed the most pronounced herd size dynamics recently, enterprises realised the most notable growth in milk yields per cow, which have more than doubled between 2000 and 2016, to 5,500 kg per head in Russia, and 4,100 in Kazakhstan (Figure S2, Appendix S2). Taken together, yield increases slightly over-compensated the drop in cow numbers in Russian enterprises, so that the

³Households typically keep one to two head of cattle, individual farms up to 150, and enterprises several hundred or even thousands (Appendix S2; Petrick and Oshakbaev, 2015), where on specialised dairy farms more than half of the cattle would be cows.

volume of milk produced in enterprises went up in recent years. Milk produced in individual farms also increased, but here the growth in cow numbers was the more important driver, as yields have stagnated during this century. Total milk production hardly changed (Figure S2, Appendix S2), as household production decreased at the same time. In Kazakhstan, the amount of milk produced domestically grew in recent years by about 2–3% annually. This aggregate growth was entirely due to (both herd size and yield) growth in enterprises and individual farms, whereas household production stayed constant.

As a main trend, enterprises recently expanded their production mostly by yield increases, especially in Russia, whereas individual farms enlarged their herd sizes. The single biggest dairy enterprise in Russia, EkoNiva-APK headed by Stefan Duerr, pursued a strategy of rapid herd expansion nevertheless. Its company-wide herd size is kept in 15 milking plants located in different provinces, and four more are under construction. The herd was expected to increase by 46% from 2016 to 2017 alone, to 40,000 cows by the end of 2017 (EkoNiva, 2017).⁴

In the remainder of this article, we focus on herd growth as one important driver of aggregate production growth. Moreover, we confine our analysis to enterprises and individual farms, as these were the only farm types contributing to production growth recently. According to official statistics, these two groups of farms contributed 56% of total milk output in Russia and 23% in Kazakhstan in 2016.

3. Data Sources and Measurement Issues

3.1. Data sources and focus regions

Our data come from the multi-purpose IAMO Russia Kazakhstan Farm Survey 2015, a cross-sectional survey of 800 agricultural enterprises and individual farms conducted in Belgorod, Riazan, Stavropol, Altai Krai and Novosibirsk provinces in Russia and in Akmola province in Kazakhstan. These six provinces were selected purposefully to represent the main agricultural regions in Russia, including black earth and non-black earth as well as European and Siberian provinces, and one of the major grain producing provinces in Kazakhstan. Among the 79 regions for which Rosstat reported milk production by agricultural enterprises and individual farms in 2015, the provinces covered here held the following ranks: Altai Krai 6, Novosibirsk 11, Belgorod 14, Riazan 19, Stavropol 33.⁵ Akmola has rank 7 among 16 provinces in Kazakhstan.

Within the provinces, a stratified two-stage random sampling procedure was used to identify farmers to be interviewed: in the first stage, districts (raions) were selected purposefully from different parts of the provinces, in the second stage, farmers were selected randomly from farm registries provided by the local public administration of these counties. Professional enumerators held face-to-face interviews with farm managers between July and October 2015.

While cross-sectional in nature, the questionnaire used in the interviews contained several recall questions, so that data on livestock numbers for 2015 and 2012 can be extracted. Data on farm management practices refer to the 2014/15 growing season.

⁴The approach of replicating plants in different locations resembles the strategy of Fair Oaks farms in the US (Boehlje and Gray, 2009).

⁵The top three regions in milk production by enterprises and farms were Tatarstan, Krasnodar and Bashkortostan.

In addition, certain land ownership and land use data are also available for earlier points in time, which are used to define instrumental variables in the regression analysis below.

We focus on data from a total of 180 dairy farms among the 800 in the full survey. Our definition of a dairy farm is that the number of dairy cows kept by this farm is positive in either 2012 or 2015 or both. Tables S1 and S2 in Appendix S1 show that 82% of all farms in our sample kept dairy cows in both periods, whereas 13% entered during the 3-year period and only 2% farms gave up dairy production.⁶ Table 1 shows that the herd size of the average respondent in the sample grew, from 201 to 247 cows. Figure S3 (in Appendix S1) illustrates the shift in the herd size distribution from 2012 to 2015. Mean herd size of agricultural enterprises was almost ten times that of individual farms. However, the distribution appears much less polarised than farm size distributions reported for other transition economies in the 1990s (Sarris *et al.*, 1999; Rizov and Mathijs, 2003).

Among the 174 farms for which herd sizes in both years are known, agricultural enterprises added 101 cows per farm on average or 7,902 in total, starting from an aggregate number of 30,503, whereas individual farms added 13 cows on average or 1,275 in total, starting from 3,745. Self-reported milk yields per cow were slightly higher on enterprises compared to individual farms (mean values of 4,900 vs. 4,700 kg/year), but the difference is much smaller than reported in official statistics (Figure S2, in Appendix S1).⁷ For the average farm in the sample, milk sales contribute less than a half to total farm revenue. As the survey data show, most farms also sell grain. 10% of farms which kept cows in 2015 did not sell any raw milk in this year, many of which were small farms using the milk for self-consumption or small processing.

The aggregate cow herd of our sampled farms was 34,248 heads in 2012, which grew by 26.8% to 2015 (including new entrants; $N = 174$). This is much more than the growth rate reported by the national statistical agencies. The official number of cows in the six provinces in enterprises and individual farms combined went up from 589.2 to 591.2 thousand cows between 2012 and 2015, an increase by 0.33%. Growth in individual farms is reported to be 68.9%, whereas the number of cows in enterprises declined by 0.3% in the same period. A likely reason for the higher growth in our sample is that, because our 2012 data rely on retrospective information from farms surveyed in 2015, operators that ceased to exist between 2012 and 2015 are not included in the sample. By contrasting our survey outcomes with census and other official data, we investigate this point in detail in Appendix S2.

There are 24 farms newly entering dairy production in the sample, i.e. they reported zero cows in 2012 and positive cow numbers in 2015. Five of them established dairy herds of 100 cows or more between 2012 and 2015, all of which were agricultural enterprises. At the same time, 15 individual farms set up new dairy herds, or 62.5% of

⁶Information on cow numbers is missing for two farms in 2015 and for four (other) farms in 2012 (i.e. 3% of all dairy farms in the sample), so that growth indicators can only be calculated for 174 farms. The following tables and figures are always based on the maximum number of observations available for that table or figure.

⁷Especially for smaller farm holdings, official statistics may be partly based on milk quantity and headcount estimates by enumerators rather than interviews with farmers. Enumerators may have an incentive to overstate the number of cows (footnote 2), which may lead to a downward bias in published milk yields.

Table 1
Descriptive statistics of variables

Variable	Pooled sample ($N = 180$)				Agricultural enterprises ($N = 82$)			Individual farms ($N = 98$)	
	Mean	Median	Min	Max	N	Mean	Median	Mean	Median
<i>Dairy herd indicators</i>									
Number of cows in 2015	246.9	60	0	3,000	178	485.8	367.5	51.9	11.5
Number of cows in 2012	201.4	42.5	0	2,000	176	396.3	300	39.0	8
Cows in 2015 – cows in 2012	52.7	4	–343	1,000	174	101.3	24.5	13.3	3
Proportionate change of dairy herd 2012–2015	0.37	0.13	–1	6.71	150	0.31	0.05	0.41	0.02
Log herd 2015 – log herd 2012 incl. new entrants	0.53	0.20	–3.91	6.91	174	0.62	0.11	0.47	0.30
Annual milk yield (kg/cow)	4,798.5	4,500.0	800.0	10,000.0	165	4,910.2	4,500.0	4,705.3	4,500.0
Share of milk sales in total farm revenue	0.42	0.41	0.00	1.00	123	0.40	0.31	0.44	0.43
Entered dairying after 2012 (1/0)	0.13	0	0	1	180	0.11	0	0.15	0
<i>Output and input prices</i>									
Milk price (USD/kg)	0.33	0.28	0.15	0.83	180	0.30	0.28	0.36	0.28
Agricultural wage (USD/month)	218.1	166.0	0.1	3,964.0	180	253.1	160.4	188.8	198.2
Concentrate price (USD/ton)	136.3	123.3	0.0	2,166.7	180	157.1	131.7	118.8	123.3
<i>Resource endowments & subsidies</i>									
Land cultivated 2009 (ha)	2,064.9	45.0	0.1	30,000.0	177	3,890.5	1,000.0	559.2	5.0
Land owned when farm was established (ha)	1,960.5	40.0	0.1	39,918.0	172	3,755.2	395.0	539.7	10.0
Land with fodder crops (ha)	701.8	30.0	0.0	17,420.0	180	1,215.3	148.5	272.1	15.0
Permanent workers in 2012 (heads)	43.5	7.0	0.0	550.0	170	88.6	51.5	8.7	2.0
Salvage value of livestock (USD/LU)*	485.9	390.6	0.0	9,500.0	177	264.1	56.2	673.0	563.5
Credit rationed farm (1/0)	0.41	0	0	1	180	0.37	0	0.44	0
Farm received livestock subsidy (1/0)	0.09	0	0	1	180	0.11	0	0.07	0
Livestock subsidies received (USD)	636.0	0.0	0.0	20,000.0	180	922.9	0.0	396.0	0.0
<i>Human capital and technology level</i>									
Age of the manager (years)	47.4	47	28	78	180	47.1	46	47.7	47
Age of the farm (years)	17.3	12	0	86	180	24.5	15	11.2	10

Table 1
(Continued)

Variable	Pooled sample (N = 180)				Agricultural enterprises (N = 82)				Individual farms (N = 98)			
	Mean	Median	Min	Max	N	Mean	Median		Mean	Median		
Share of hired workers in total	0.71	1	0	1	180	0.89	1		0.57			0.63
Uses pregnancy tests (1/0)	0.18	0	0	1	175	0.27	0		0.10			0
Uses artificial insemination (1/0)	0.38	0	0	1	175	0.51	1		0.28			0
Manager has agricultural education (1/0)	0.40	0	0	1	180	0.59	1		0.24			0
<i>Vertical coordination</i>												
Individual farm (1/0)	0.54	1	0	1	180	0.00	0		1.00			1
Farm belongs to an agroholding (1/0)	0.10	0	0	1	180	0.18	0		0.03			0
Sells milk under contract (1/0)	0.62	1	0	1	169	0.77	1		0.49			0
<i>Regional distribution</i>												
Belgorod province (1/0)	0.13	0	0	1	180	0.01	0		0.22			0
Riazan province (1/0)	0.23	0	0	1	180	0.37	0		0.12			0
Stavropol province (1/0)	0.08	0	0	1	180	0.15	0		0.03			0
Altai Krai province (1/0)	0.22	0	0	1	180	0.37	0		0.09			0
Novosibirsk province (1/0)	0.21	0	0	1	180	0.07	0		0.32			0
Akmola (KZ) province (1/0)	0.13	0	0	1	180	0.04	0		0.21			0

Notes: Data refer to 2014/5 growing season unless stated otherwise.

*LU = livestock unit; using the following coefficients: cattle, cows, camels = 1; horses = 0.8; pigs = 0.3; sheep, goats = 0.1; poultry = 0.01.

Source: IAMO Farm Survey 2015.

all new entrants. Their share among entrants is thus slightly higher than among all farms in the sample (54%). As a comparison of means and median values demonstrates, herd size distributions are highly skewed to the right. The Kernel densities of the distributions of herd sizes in Figure 1 show that taking the natural logarithm makes them approximately bell shaped for individual farms and agricultural enterprises separately, with peaks at around 5 and 500 cows. Given this, we log transformed all scale-sensitive variables used in the subsequent regression models. Zero values were replaced by $\log(1)$ for subsidy levels and by $\log(0.1)$ for land, workers, and other monetary variables. These were measured in US dollars (USD), using an exchange rate of 60 Russian ruble (RUB) per USD and 185 Kazakhstani tenge (KZT) per USD. Missing prices per farm were replaced by provincial median prices from the survey in 46 cases, to keep these observations in the sample.

3.2. Measuring herd growth using the survey data

We consider a range of options for measuring herd growth, focusing on: the dispersion of the resulting growth variable; the treatment of zero observations; the resulting effect on sample size. All these have implications for the tractability of the herd growth measure in subsequent regression analysis.

The simplest measure of herd growth is absolute change in cow numbers between 2012 and 2015. This specification uses all available observations but results in a highly dispersed growth measure with many apparent outliers. A common remedy is to use the logarithmic transformation, which is however not defined for non-positive values. Replacing zero with a small positive value (0.1) and using the logarithm of the absolute value of change multiplied by -1 for shrinking farms creates the following definition of growth:

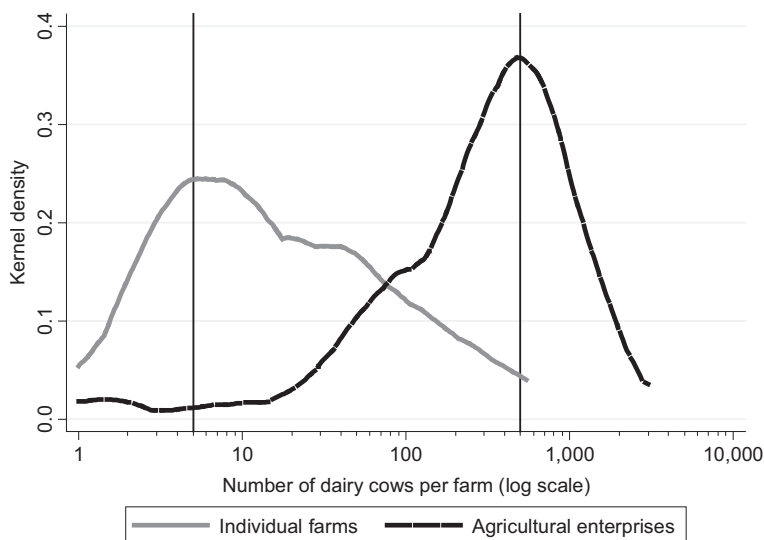


Figure 1. Distribution of herd sizes by farm type in 2015

Note: Based on farms with non-zero and non-missing observations in 2015 ($N = 171$).

Source: Authors, based on IAMO Farm Survey 2015.

$$g_{i1215} = \begin{cases} \log(H_{i15} - H_{i12}) & \text{if } H_{i15} > H_{i12} \\ \log(0.1) & \text{if } H_{i15} = H_{i12} \\ -\log(-(H_{i15} - H_{i12})) & \text{if } H_{i15} < H_{i12} \end{cases}, \quad (1)$$

where g_{i1215} is the growth of the herd size between 2012 and 2015, H_{i12} is herd size measured as number of dairy cows in 2012 per observed farm i , and H_{i15} is herd size in 2015. This specification keeps the entire sample available for analysis and results in a reasonably compact distribution (Figure 2).

A second way to calculate growth is by computing proportionate change, i.e.

$$g'_{i1215} = \frac{H_{i15} - H_{i12}}{H_{i12}}. \quad (2)$$

In our dataset, this approach leads to a moderately dispersed distribution of g'_{i1215} but it is not defined for new entrants where $H_{i12} = 0$. Assigning one hypothetical cow in 2012 to new entrants restores the full sample, but exacerbates the dispersion and outlier problem. For example, the new entrant with the biggest dairy herd in 2015 kept 1,000 cows, implying an average annual proportional growth of 33,300%.

Alternatively, one could follow the logarithmic approximation of proportionate change used in most of the econometric literature on farm growth to date (e.g. Sumner and Leiby, 1987; Weiss, 1999) and calculate growth as:

$$g''_{i1215} = \log H_{i15} - \log H_{i12}. \quad (3)$$

In this formulation, the dispersion of herd sizes is narrowed via the log transformation. This measure is also not defined for zero herd size in either 2012 or 2015. Replacing zero observations for herd size with one hypothetical cow restores the maximum

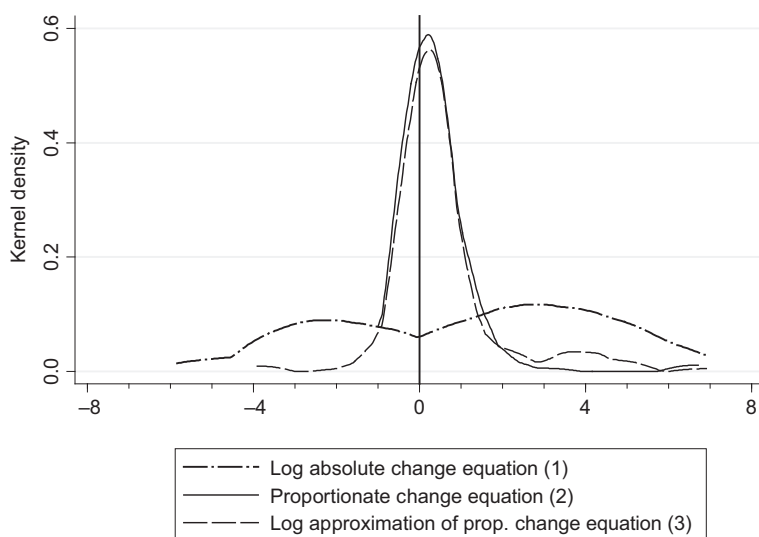


Figure 2. Distribution of three alternative herd growth measures

Note: Proportionate change is without new entrants and the log approximation with zero herd size replaced by one.

Source: Authors.

sample available, but inflates the sample dispersion much less than by using equation (2).

Figure 2 shows that log absolute change is bimodally distributed. The two proportionate change measures follow a stylised normal distribution, whereby proportionate change has its left tail truncated at -1 . The log approximation generates five values lower than -1 in cases of particularly drastic herd size shrinkage or complete herd abandonment. In the following, we present regression results for all three measures displayed in Figure 2.

4. Hypotheses and Econometric Specification

4.1. Determinants of herd growth

Static production theory suggests that a profit maximising farmer will, *ceteris paribus*, respond positively (increasing herd size) to milk prices and negatively to the prices of complementary inputs (such as concentrate fodder), which (Foltz, 2004) also holds for dynamic settings with sunk costs and uncertainty. *Ceteris paribus*, under such conditions, herd growth will also be more profitable and thus higher if the salvage value of the livestock herd is lower.

In addition, the recent farm growth literature has paid a lot of attention to the interaction of quasi-fixed factors such as operational scale, technology and management. Weiss (1999) found that herd growth was attracted by two distinct focal points of about 2 and 70 cows in census data for Upper Austria collected in 1985 and 1990. On the other hand, Mosheim and Lovell (2009) found evidence in favour of increasing returns to scale among US dairy farms surveyed in 2000 up to a herd size of about 1,000 head. Management ability as a potentially lumpy input thus likely plays a major role in the determination of actual growth patterns (Sumner, 2014). Moreover, Jovanovic's (1982) model of evolutionary learning implies that growth rates will decrease with the age and the size of the firm and the manager's ability to learn in a stochastic environment (Rizov and Mathijs, 2003).

A recent feature of post-Soviet restructuring is the emergence of agroholdings, i.e. vertically and horizontally integrated agro-industrial conglomerates often funded by non-agricultural investors (Rylko *et al.*, 2008). Agroholdings may well upgrade machinery and equipment, which may also generate growth in herd size, and reform management practices.

Policy influence will likely be different in Western and post-Soviet countries. Subsidy schemes in Russia and Kazakhstan come in the form of direct transfers tied to livestock-related expenses or as interest subsidies (OECD, 2013, 2017).

Following this brief review, we hypothesise that dairy herd size at the farm level is determined by six sets of factors:

- 1 Output and input prices,
- 2 resource endowments,
- 3 human capital and technologies employed,
- 4 various dimensions of vertical coordination,
- 5 subsidies,
- 6 regional fixed effects.

We expect that farms with greater fodder production potential as measured by land allocated to fodder crops, and with more workers, will grow faster if these potentials

are not yet fully utilised. We thus control capacity utilisation and initial specialisation in dairy by also including initial herd size in the analysis.

In addition, more able and better-trained managers are expected to manage larger herds (Sumner and Leiby, 1987). Similarly, using best practice technologies (such as pregnancy tests and artificial insemination) is also hypothesised to encourage herd growth. Our milk yield data relate to the end of the observed period and thus cannot serve as an exogenous measure of management quality. Figure S4 (Appendix S1) suggests that yields are slightly higher at the tails of the herd size distribution, but according to the confidence interval, this hypothesis is hard to maintain against the null of a flat line.

Following Jovanovic (1982), older firms are assumed to grow less. Distinct from older firms, older managers often possess more human capital, which they may have acquired on different firms. But they have also further progressed in their lifecycle and may thus have a lower propensity to invest as they are approaching pension age (Weiss, 1999; Rizov and Mathijs, 2003).

We suppose that credit rationed farms will grow more slowly. Following Petrick *et al.* (2017), we consider a farm to be credit rationed if the manager applied for a loan and was rejected or would have liked to borrow more at the going interest rate. We also classify managers as rationed if they refrained from borrowing because they feared the risk of defaulting on the loan or regarded the application procedures as too complicated (risk rationing and transaction cost rationing).

We consider both the total number of permanent workers on the farm in 2012 and the share of hired workers. Note that on average, more than half of the workers on individual farms are hired, not family members (Table 1). Moreover, we test whether farm type or partnership in an agroholding have a direct effect on herd growth, where local managers were asked if their operation belongs to an agroholding. We also hypothesise that marketing under contract allows farmers to keep bigger herds and instigate higher growth (Gorton *et al.*, 2007).

We hypothesise that more subsidies lead to higher growth (or slower shrinkage). In the survey, farmers were asked to quantify the cash value of the livestock-related subsidies, which include subsidies on livestock sales and on inputs for livestock as well as interest subsidies on loans.

Finally, we assume fixed effects by province, which are not captured by the other explanatory variables, to capture regional market structures and natural conditions. Moreover, to mitigate the influence of the arbitrary assignment of $\log(1)$ values for farms with zero cows in 2012, we include a separate dummy variable for this group of observations. Effects on herd growth for this subgroup are then estimated not relative to zero growth but relative to the conditional mean growth of all entering farms.

Unfortunately, we lack good measures of livestock-related capital stock and technology other than herd size and the management practices. Nor do we have any information on off-farm incomes for individual farmers or the demographic characteristics of farm families.

4.2. Econometric specification

Since some of the herd growth determinants may also be outcomes of farm decision-making, OLS estimation would be inconsistent. A standard approach to address this endogeneity is to use instruments, such as lagged values with panel data. Although we have lagged values from retrospective survey questions, our cross-sectional data are

limited. We therefore use a recursive multi-equation model of herd growth following Roodman (2011) and Dong *et al.* (2016).⁸

We consider separate equations for the initial number of dairy cows in 2012 and the level of subsidies. As some farms kept no cows in 2012 and only some received subsidies, both variables are censored. As noted above, we use three different specifications for the main dependent variable (herd growth, g_{i1215}), while the censoring in log terms is also explained above:

$$g_{i1215} = \alpha_a h_{i12} + \beta_{s_i} + x'_{ai} \theta_a + \epsilon_{ai}, \quad (4a)$$

$$h_{i12} = \begin{cases} 0 & \text{if } H_{i12}^* \leq 0 \\ x'_{bi} \theta_b + \epsilon_{bi} & \text{if } H_{i12}^* > 0 \end{cases} \quad (4b)$$

$$s_i = \begin{cases} 0 & \text{if } S_i^* \leq 0 \\ \alpha_c h_{i12} + x'_{ci} \theta_c + \epsilon_{ci} & \text{if } S_i^* > 0 \end{cases} \quad (4c)$$

with $\epsilon = (\epsilon_{ai}, \epsilon_{bi}, \epsilon_{ci})' \sim N(0, \Sigma)$,

where h_{i12} is log herd size in 2012, x_i is an equation-specific vector of determinants including a constant, i denotes the observations in the sample, α , β and θ are parameter vectors to be estimated, ϵ_i is an equation-specific error term, s_i is log subsidies received, H_{i12}^* is a partly latent herd size index in levels, and S_i^* is a partly latent subsidy index. Equation (4b) also includes the variables land owned when the farm was established, land cultivated in 2004 and land cultivated in 2009 and their interactions and square terms as instruments. The estimator maximises the joint likelihood function of the system of equations (4a)–(4c), assuming that the error terms follow a joint normal distribution. Estimation was carried out using the conditional mixed-process (cmp) routine by Roodman (2011) in Stata 15.

5. Results

We present findings for three measures of herd growth: log absolute change as defined in equation (1), proportionate change as in equation (2) and a log approximation of proportionate change as in equation (3). Absolute change may be the measure preferred by policy-makers, as it quantifies the effects of herd growth determinants in terms of number of cows added, a primary policy goal. On the other hand, as shown below, relative measures permit statements about herd size dynamics that may be more interesting from an analytic point of view. As the measures complement each other, we show results for all of them.

5.1. Absolute herd growth

Table 2 presents the parameter estimates for equations (4a)–(4c) for log absolute herd size change. The results provide no evidence that the change in absolute cow numbers depends on initial herd size or on available land or labour resources. However, farms

⁸Estimation in simultaneous equations is more efficient than, for example, a single equation instrumental variables approach, because it takes into account the full covariance structure of the system of equations. Moreover, in the presence of missing observations for some variables, data utilisation is also more efficient, as the estimating sample is defined per equation, not for the system as a whole (Roodman, 2011).

with a higher share of hired labour grow faster. In addition to the concentrate price, the availability of marketing contracts is another important driver of herd expansion. Contrary to the implications of the evolutionary learning literature (Jovanovic, 1982), longer established farms grow faster.⁹ Moreover, faster growing enterprises make more use of pregnancy testing. Neither membership in an agroholding nor credit rationing status nor the measurable personal characteristics of the manager seem to influence herd growth. In a separate specification, we included age square, but failed to find a non-linear effect on growth. However, a 10% increase in subsidies to individual farms would increase cow numbers on these farms by about 4% over three years.

In the light of theoretical expectations, the highly significant and negative coefficient for milk price is surprising. We discuss this below.

Variation in initial herd size in 2012 can be statistically explained fairly well by provincial dummy variables and the set of additional instruments measuring land endowments and land use and their interactions (model B in Table 2).

The results of model C indicate that younger farms were significantly more likely to obtain subsidies than older farms. In addition, initially bigger herds are more likely to receive subsidies and they obtain larger amounts (both aspects are modelled simultaneously by the censored regression model). Individual farms receive significantly more subsidies than enterprises, about 14.5% more, according to the parameter estimate reported in Table 2, whereas the share of hired workers does not play a role here.¹⁰

Both variables measuring management practices had a statistically significant influence on subsidies, but somewhat surprisingly, with different signs: the practice of pregnancy testing lowered subsidy absorption, whereas artificial insemination increased it. A possible explanation for the negative effect of pregnancy tests is that farmers receiving subsidies for enlarging their herd buy pregnant cows rather than raising them from their existing herd. In our sample, 38% of dairy farmers who received livestock subsidies said that they had bought animals in the past year. Such farmers may not (yet) practice pregnancy testing, so that this indicator in fact measures the source of the animals added to the herd. The negative sign may thus imply that farmers receiving subsidies buy cows more often than non-recipients. Indeed, only 16% of dairy farmers not receiving subsidies said that they bought livestock in the previous year.

5.2. Relative herd growth

Results for relative herd growth are displayed in Table S3, Appendix S1, for the measure defined in equation (2) and in Table S4, Appendix S1, for the measure defined in equation (3). For these measures, testing whether $\alpha_x = 0$ in equation (4a) (initial herd size in 2012) is an elementary test of Gibrat's law (Weiss, 1999). In fact, we find that other than for absolute growth, relative growth measures *do* display a systematic relation to initial herd size: larger farms grow significantly less. We explore this pattern further below. Otherwise, most of the findings for absolute growth are confirmed by

⁹10% of dairy farms in the sample were established between 2012 and 2015, the rest were founded earlier.

¹⁰Individual farms with small herd sizes should be formally eligible to receive subsidies, as both governments run special subsidy programmes designed to reach small and also beginning farmers. However, informal allocation rules due to the discretionary power of local administrators or specific co-financing rules may exclude small farms in reality (Wegren, 2015; Gataulina *et al.*, 2016).

Table 2
Regression results of log absolute herd growth 2012–2015

	Log absolute herd size change equation (1) (A)		Log dairy cows in 2012 (B)		Log livestock subsidies (C)	
	Coeff.	P-val.	Coeff.	P-val.	Coeff.	P-val.
Log dairy cows 2012	0.3	0.645	–		4.8	0.109
Log dairy cows 2012 squared	–0.1	0.322	–		–	
Log milk price	–3.1***	<0.001	–		–	
Log agricultural wage	0.3	0.213	–		–	
Log concentrate price	–0.3**	0.043	–		–	
Log livestock value	0.0	0.896	–		–	
Log livestock subsidies	0.4*	0.093	–		–	
Log fodder land	0.1	0.383	–		0.4	0.480
Log perm workers 2012	–0.2	0.398	–		1.3	0.424
Age of manager	<0.1	0.456	–		0.3	0.377
Age of farm	0.1***	0.003	–		–0.4**	0.010
Share of hired workers	1.1*	0.050	–		3.4	0.598
Pregnancy tests (1/0)	1.7**	0.038	–		–17.7***	<0.001
Artificial insemination (1/0)	0.3	0.673	–		18.2***	<0.001
Agric education (1/0)	0.4	0.497	–		–0.3	0.955
Agroholding (1/0)	–0.8	0.456	–		1.1	0.830
Credit rationed (1/0)	0.5	0.278	–		4.4	0.237
Milk contract (1/0)	1.1***	0.017	–		–14.4***	0.001
Individual farm (1/0)	–0.1	0.910	–		14.5***	0.001
New entrant (1/0)	3.0***	0.006	–		8.4	0.311
Riazan (1/0)	1.6	0.108	1.9***	<0.001	1.4	0.832
Stavropol (1/0)	–2.6*	0.052	–0.5	0.704	15.1	0.105
Altai Krai (1/0)	>–0.1	0.974	–0.3	0.732	4.3	0.492
Novosibirsk (1/0)	0.6	0.514	–0.9*	0.052	–2.9	0.651
Akmola (KZ) (1/0)	1.5*	0.097	–0.8	0.261	–5.0	0.496
Constant	–7.2***	0.002	1.1***	0.004	–55.9***	<0.001
<i>Additional instruments</i>						
Land owned when farm was established (LEST)	–		0.2	0.107	–	
Land cultivated in 2004 (L04)	–		–0.4	0.318	–	
LEST * L04	–		<0.1	0.852	–	
Land cultivated in 2009 (L09)	–		0.5	0.136	–	
LEST * L09	–		>–0.1	0.671	–	
L04 * L09	–		0.2*	0.096	–	
LEST * L04 * L09	–		>–0.1	0.275	–	
LEST ²	–		<0.1*	0.053	–	
L04 ²	–		–0.1*	0.073	–	
L09 ²	–		–0.1	0.356	–	
N			172			

Notes: Equations A – C simultaneously estimated by Maximum Likelihood using the conditional mixed process estimator by Roodman (2011). * (**, ***): significantly different from zero at the 10 (5, 1) % level.

Source: Authors.

either model D or G or both. These models provide additional evidence that the milk price level, subsidies, farm age, share of hired workers, pregnancy testing and contract marketing affect growth, and the parameters allow us to quantify the strength of their effects.¹¹ Also the findings on the determinants of subsidy uptake are widely similar.

For comparison, we provide single-equation growth regressions based on OLS for the three dependent variables in Table S5 in Appendix S1. The results are widely consistent with the findings presented so far and allow a judgement of model fit based on the R^2 indicator not available from maximum likelihood estimation. We consider model fit satisfying for absolute and proportionate growth and quite good for the log approximation. We tested for multicollinearity by calculating variance inflation factors, these were entirely smaller than 5 and thus considered uncritical. Table S5 includes results by farm type for the log approximation of proportionate growth, the indicator used most widely in the literature. Due to the small sample size, we could not estimate the multi-equation model by farm type. Growth rates on enterprises increase in fodder land and the share of hired workers, and decrease in the age of the manager, whereas milk contracts do not affect growth in this category of farms (model M). Growth of individual farms is determined only by the initial herd size, the milk price, and milk contracting (model N). But note that the P -value for subsidies only slightly misses the 10% level.

6. Discussion

6.1. Growth patterns

Several of the key findings on growth patterns among Russian and Kazakhstani dairy farmers are illustrated by Figure 3, which plots the predicted growth in number of cows per year implied by the parameters of model G along with a 95% confidence interval at geometric sample means of all other variables. First of all, dairy herds in Russia and Kazakhstan *do* grow, and this growth is significantly positive up to a herd size of about 70 cows – the intersection point of the lower confidence interval boundary with the horizontal axis indicating zero growth. Second, consistent with most empirical literature on dairy herd growth, our finding rejects Gibrat's law of farm growth independence from initial size (Weiss, 1999; Rizov and Mathijs, 2003).

The equilibrium herd size implied by the growth path in Figure 3 is around 130 cows (as indicated by the solid vertical line). However, the widening confidence interval suggests that growth is largely undetermined by current herd size for herd sizes above the equilibrium number of cows, a finding consistent with an L-shaped average cost curve found in other country contexts (Mosheim and Lovell, 2009).

The insignificance of the quadratic terms for herd size in models D and G suggests that the relationship between herd size and growth rates is log linear. According to the OLS model L (Table S5, in Appendix S1), individual farms display a slightly flatter and more convex growth path than enterprises, with an intersection of the two lines somewhere below 100 cows, though the confidence intervals of the two growth lines widely overlap.

¹¹For example, a relative growth rate induced by pregnancy testing of 1.6 in three years is equivalent to a rate of $1.17 = \sqrt[3]{1.6}$ in one year.

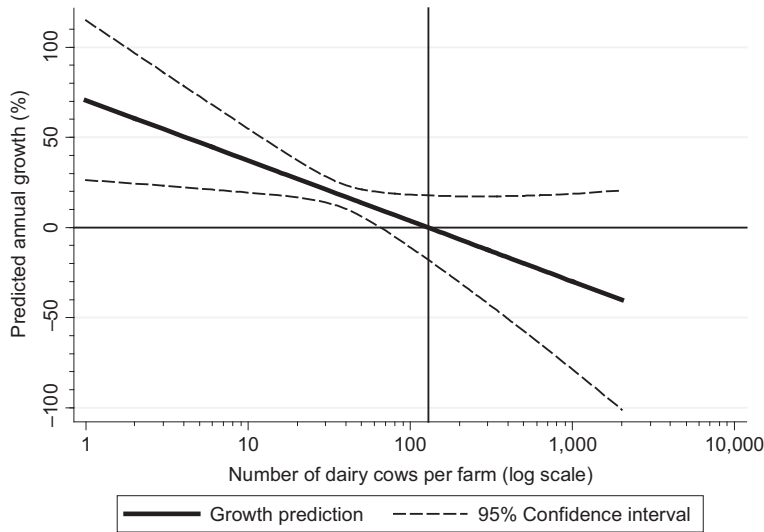


Figure 3. Predicted growth path based on parameters of multi-equation model
Note: Prediction evaluated at geometric sample means, based on parameters of model G.
Source: Authors.

6.2. Vertical coordination and the role of milk prices

At first glance, the finding of a negative effect of the farm gate price of milk on growth seems difficult to explain. While inconsistent with standard microeconomic models of supply response, the literature has documented various cases of inelastic milk supply with regard to output prices (e.g. Huettel and Jongeneel, 2011). The common argument is that herd growth is tied to other resources which are fixed in the short run, so that growth is retarded. In particular, farmers may not be able to acquire the land necessary for fodder production or manure disposal. In the EU, growth has been limited by production quotas. Otherwise less competitive farmers may be more reluctant to exit farming and release their resources for others' expansion if prices are high (Zimmermann and Heckeley, 2012, p. 598). In addition, labour shortages may constrain growth.¹²

However, these explanations are less plausible in a Russian and Kazakhstani context. There exist no production quotas and manure regulations should pose little constraint on dairy expansion. There is a long tradition of hiring workers for large-scale livestock operations, although managers increasingly complain about the difficulties in finding skilled workers (Petrick *et al.*, 2013).

When we interacted the milk price with herd size, the negative direct price effect in the regression disappeared. Milk prices thus have no growth effect if the negative correlation with herd size is taken into account. Moreover, a milk price regression (Table S6 in Appendix S1) confirms that farms with larger herds obtain lower prices.

¹²As pointed out by one journal referee, herd growth may also be determined by the manager's expectations about fluctuating milk prices. High prices may lead to lower herd growth, as low prices are expected in the next season. Unfortunately, a lack of sufficiently detailed periodical data prevents us from testing this hypothesis.

Why so? Beyond a residual category of 'other' sales channels with generally low prices, farmers report four distinct marketing channels as their main milk outlets: direct sales to consumers, independent traders, dairy processors and state procurement. Price mark-ups are highest for direct sales (on average 68% higher than prices in the category 'other'), followed by traders (59%), processors (49%) and state procurement (47%). Small dairy farmers often sell directly, whereas enterprises deliver to processors or state procurement.¹³

Marketing contracts tend to increase the price as well (about 9% compared to spot markets), but this variable is only significant at 15%. Individual farms and new entrants realise lower prices than enterprises and established farms (about 13% on average). Finally, there are significant differences in the price level across regions, with Akmola in Kazakhstan offering the highest price mark-up of 24% compared to the reference region Belgorod.

Respondents were also asked about the specific contractual obligations implied by their marketing contract. With contracting limited to the specification of milk sales alone as the default, 7% of farmers marketing under contract stated that their buyer would also participate in production decisions and quality control (management contract), whereas only 5% said that their buyer also provided credit, inputs or services (resource contract, Dries *et al.*, 2009).

Only 7% of dairy producers said they cooperated with other farmers for production, machinery use or marketing, but this had no effect on the milk price they received (Table S6). Unfortunately, our data do not allow us to examine the effects of milk quality and the seasonality of milk prices. According to Serova and Karlova (2010), inadequate milk quality in terms of bacterial contamination and somatic cell count used to be a common problem in these countries.

6.3. Subsidy effects

Evidence on positive subsidy effects comes from both the absolute herd growth model A and log approximation of proportionate change model G. The subsidy elasticity of absolute herd growth in model A suggests that cow numbers increase by 4% with a rise in subsidies of 10%. In absolute terms, subsidies needed to be raised by 1,540 USD per farm to add about one cow in three years (calculated at the geometric mean of farms who obtained subsidies). However, less than 10% of dairy farms in our sample received any livestock subsidies (Table 1).

The parameter estimate for the subsidy effect reported for model G in Table S4 also suggests a non-linear effect of subsidy payments on herd growth. The marginal effect of an additional subsidy strongly decreases with the subsidy level up to about 5,000 USD per farm, after which it converges to zero. The first 300 USD of subsidy induce a growth effect of about 2% per year. The effect declines for higher payments. So the actual effect on herd growth is the strongest for small amounts, controlling for initial herd size.

¹³Indeed, Pallot and Nefedova (2007, p. 193) argue that the most lucrative outlets for small producers in Russia are local food markets in the vicinity of urban agglomerations or along main-line roads and railways, where small quantities can be sold to second home owners and urban commuters. Dairy processors and other formal organisations are the least preferred customers, as they pay the lowest prices and quality standards may be higher. Milk trade by informal intermediaries who pick up the milk at the farm gate ranges somewhere in between.

7. Conclusions

Commercial Russian and Kazakhstani farm operators in our sample increased their dairy herds if they employed good management practice and if they had access to milk marketing contracts. For example, holding other farm characteristics constant, farms on which regular pregnancy testing was practiced grew about 17 percentage points more per year on average than their peers. The following thought experiment may illustrate this number: if 55% of cows in Russia were kept by enterprises and individual farms that do not practice pregnancy testing (as in the sample) and if these cows had a milk yield of 4.4% below the average (as in the sample), a 17% increase of their aggregate milk output would equal to roughly two million tons extra, or 25% of Russia's milk imports in 2015.

The effect of participation in marketing contracts has a similar scale and is more pronounced for individual (family) farms than for corporate farms. Small farms grow more than large farms, with a predicted equilibrium herd size of around 130 cows. However, for herds above this threshold, growth is no longer determined by size. Individual farms and agricultural enterprises may follow distinct growth paths, but the differences are not estimated precisely enough to be significant.

We confirm the importance of reliable vertical coordination for dairy expansion in a post-socialist context, but our results partly qualify the existing literature. Other than Sauer *et al.* (2012), we establish a negative rather than a positive relationship between herd size and milk price. The reason is fairly obvious: Sauer *et al.* consider only farms that sell exclusively to commercial processors, whereas we also study farms that sell to consumers directly. Such direct outlets can absorb only a limited volume of produce. We find only very few cases of resource providing contracts in the spirit of Dries *et al.* (2009) (5% of respondents), and such arrangements did not appear to have an effect on growth.

Less than 10% of dairy farms in our sample received livestock subsidies and these few farmers tended to be younger and with larger herds than their peers, although they did not necessarily belong to vertically integrated agroholdings. Controlling for herd size and other farm characteristics, individual farms received up to 18% higher subsidy amounts than enterprises, and subsidies seem to be more effective for individual farms in creating herd growth. Our absolute herd growth regressions suggest that the current subsidy policy does little to add cows. In terms of relative growth rates, smaller farms up to 70 cows are the growth champions, not the agroholdings. Our findings indicate that on-farm herd growth will be more stimulated if many farms receive small subsidies, rather than very few receiving individually large amounts.

However, decision-makers should understand that public investments in best practices of farm management and vertical coordination promise to invigorate growth much more effectively than subsidies. In this regard, knowledge about specific herd management techniques matters more than formal education levels. This is not too surprising in an environment of rapidly changing qualification standards, a tradition of hired management and manager mobility across sectors. In addition, small farms often do not have access to value chains that generate milk prices comparable to those obtained from direct sales to consumers. Competitive dairy processing structures that connect small producers to a wide network of spatially dispersed consumers are missing. Collective action by producers themselves (such as the formation of dairy processing cooperatives) is rare at present.

Despite the weaknesses in the service environment of agriculture, we provide evidence that 25 years after the end of central planning, structural change among commercial dairy farms in Russia and Kazakhstan is in many ways similar to the patterns observed in the US, if not also in the EU more recently (Zimmermann and Heckeley, 2012; Sumner, 2014). Smaller farms catch up in terms of herd growth, at least up to a certain minimum viable herd size, and classical family-run operations coexist with vertically integrated agribusinesses based on hired labour. There is no hint that either individual farms or enterprises will soon disappear as an established type of farm organisation.

Farms with a higher share of hired labour added more cows and also grew faster in percentage terms. This finding supports the view that corporate dairy farms can be a viable alternative to family-run individual farms. We nevertheless consider it premature to conclude that super-large agrohholdings of the sort found in Russia and Kazakhstan today foreshadow future developments in the West. While individual cases of apparently successful supra-regional dairy holdings exist in Russia and Kazakhstan, only 10% of operations in our sample belonged to an agroholding (although they accounted for 23% of all cows in the sample). This suggests that even for the large majority of the 3.6 million cows currently kept in both countries in enterprises alone, such arrangements are still uncommon. Moreover, we didn't find any evidence that the integration into holding structures affected growth patterns at the level of the individual milking plant, even taking into account newly established plants. Neither was growth affected by the legal status of a corporate farm *vis-à-vis* individual farms. Even if farms with more hired labour grow faster, complementary research has shown that challenges in labour supervision and the design of payment schemes for workers persist (Petrick, 2017). Also family farms in the West are increasingly relying on hired managers, workers and service providers and are thus becoming more akin to corporate entities. With regard to these trends, commercial dairy farms in Russia may even be a few steps closer than their Western counterparts to a 'new normal' characterised by the coexistence of family and corporate ownership.

The producers of the substantial 'non-commercial' share of milk output in our study countries, the rural households, find no equivalent in the West. In line with the literature, we assumed that they have little growth potential, and we showed that their share in the aggregate cow herd has declined. But there is almost no up-to-date evidence available on this type of producer, which suggests a research task for the future.

Moreover, while identifying the factors determining dairy herd growth, we cannot clarify why, at least in Russia, dairy production has grown much less than the poultry and pork sectors. Possible reasons include a lower profitability, a longer payback period for capital investments, and higher demands on managers involving more complex production processes, such as long-term management of roughage supply and herd genetics. Further analysis is required to provide empirical evidence on these hypotheses.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. Additional Figures and Tables

Figure S1. Dairy production and consumption, Russian Federation and Kazakhstan 1990–2016.

Figure S2. Size of the domestic dairy herd and milk yields by farm type, Russian Federation and Kazakhstan 1990–2016.

Figure S3. Distribution of herd sizes in 2012 and 2015.

Figure S4. Milk yield vs. herd size in 2015.

Table S1. Number of sampled farms by dairy status in 2012 and 2015.

Table S2. Number of sampled farms keeping cows by farm type and country in 2015.

Table S3. Regression results of proportionate herd growth 2012–2015.

Table S4. Regression results of log herd size 2015 – log herd size 2012.

Table S5. Regression results of herd growth 2012–2015, single equation models.

Table S6. Regression of farm-gate milk price and descriptive statistics.

Appendix S2. Plausibility Checks of the Survey Data in the Light of Official Live-stock Statistics

Table S7. Key indicators from survey and official data compared.

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