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Productivity Growth and the Revival of Russian Agriculture

Nicholas Rada, William Liefert, and Olga Liefert

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Abstract

Russia's transition from a planned to a market economy during the 1990s resulted in a severe decline in agricultural gross output and the inputs used in production. By the late 1990s, the agricultural output decline had bottomed out and growth resumed. For some products, such as grain, the production rebound created surpluses for export, while for other products for which Russia was a net importer, such as meat, the output growth reduced imports. Although the output turnaround began in the late 1990s, input use fell until the mid-2000s as the sector continued to correct overexpansion during the Soviet period. Measures of Russian national and district-level total factor productivity (TFP) growth in agriculture from 1994 to 2013 reveal that recovery varied regionally across the country, though greater output specialization has been a general feature among districts. The most robust productivity growth occurred in the South, which has emerged as Russia's most important agricultural district. The Central district also exhibited strong TFP growth in the later years of the study period, which supports a cautiously optimistic view of Russia's future agricultural growth.

Keywords: agriculture, agroholdings, Russia, total factor productivity (TFP)

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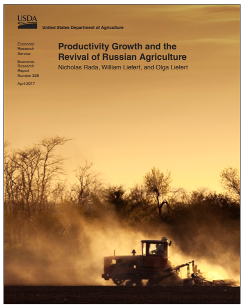

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Productivity Growth and the Revival of Russian Agriculture

Nicholas Rada, William Liefert, and Olga Liefert

What Is the Issue?

Russia's agricultural output fell during the country's transition from a planned to a market economy in the early 1990s but has rebounded strongly since the late 1990s. The production increase contributed to Russia reducing its large imports of meat and other livestock products and becoming a major grain exporter. By 2011-14, Russia supplied 12 percent of world wheat exports. Yet, the causes of the resumed growth are unclear.

Has the revivial of Russian agriculture stemmed from the adoption of new technologies and processes that boosted total factor productivity (TFP)? TFP is the ratio of total output to total aggregate inputs and is a more comprehensive measure of agricultural performance than crop yields or labor productivity because it accounts for all measureable resources of production (land, labor, materials, capital) instead of only land or labor.

Russia's districts responded in different ways to the new agricultural opportunities following the transition to a market economy, and so a district-level evaluation of productivity growth is critical to understanding the country's agricultural revival. If the growth revival was due to TFP, then which districts in Russia are driving national TFP growth and in which commodities are they specializing? To answer these questions, this study evaluates agricultural output, input, and TFP trends in Russia at the national and subnational (district) levels during 1994-2013.

What Did the Study Find?

The sharp decline in Russia's agricultural output and use of inputs (land, labor, materials, and capital) as the sector transitioned to a market economy affected all Russian districts rather equally. Greater specialization in output across districts has been a common feature of Russia's subsequent agricultural recovery. Since 2000, the South district has increased production of wheat, corn, and sunflower seed while decreasing production of potatoes and eggs. The Central district has traditionally been the country's biggest producer of sugar beets and is now the largest meat producer. Greater specialization for some districts has been achieved not so much by increasing output of particular commodities but rather by decreasing production.

At the national level, output growth rebounded in the early 2000s, but input use continued to drop until 2005. Once input growth resumed, on average across Russian districts, national TFP showed modest growth through 2013.

While overall TFP growth improved nationwide, the pattern of agricultural recovery varied widely across districts. The South and Central districts accounted for a combined 39 percent of Russia's aggregate TFP growth in 1994-99 and 51 percent in 2009-13. The South in particular stands apart from other districts by its early and sharp rebound in agricultural output, input use, and TFP growth following the transition. Since 1998, TFP growth has accounted for 69 percent of the South's 5.2-percent average annual increase in output. Relative to other districts, the South appears to have benefited from advantages in soil and climate, geography (such as proximity to the major grain-exporting ports on the Black Sea), institutions, infrastructure, and the emergence of a new type of vertically integrated producer (agroholdings).

By 2013, the other agriculturally important district in Russia, the Volga, had not yet recovered from the transition. Moreover, Russia's remaining districts in the northern and eastern parts of the country experienced stagnant (less than 1 percent per year) or negative output growth. Thus, while the South has been key to Russia's agricultural revival, progress in other districts will be crucial for accelerating future national growth.

How Was the Study Conducted?

To evaluate Russia's agricultural productivity growth from 1994 to 2013, ERS researchers applied growth-accounting estimation to construct output, input, and TFP quantity indexes for each Russian district and at the national level, using a unique dataset drawn from Russia's Ministry of Agriculture and Federal Service of State Statistics. TFP growth is defined as the difference between agricultural output growth and the weighted sum of land, labor, capital, and materials growth in the sector. Each input's aggregation weight is obtained from its relative share of total expenditures; each output's aggregation weight is obtained from its relative share of total revenues. A comprehensive dataset was assembled to identify whether TFP was the primary source of Russia's resumed agricultural growth, which districts achieved the fastest TFP growth, and in which commodities they specialized.

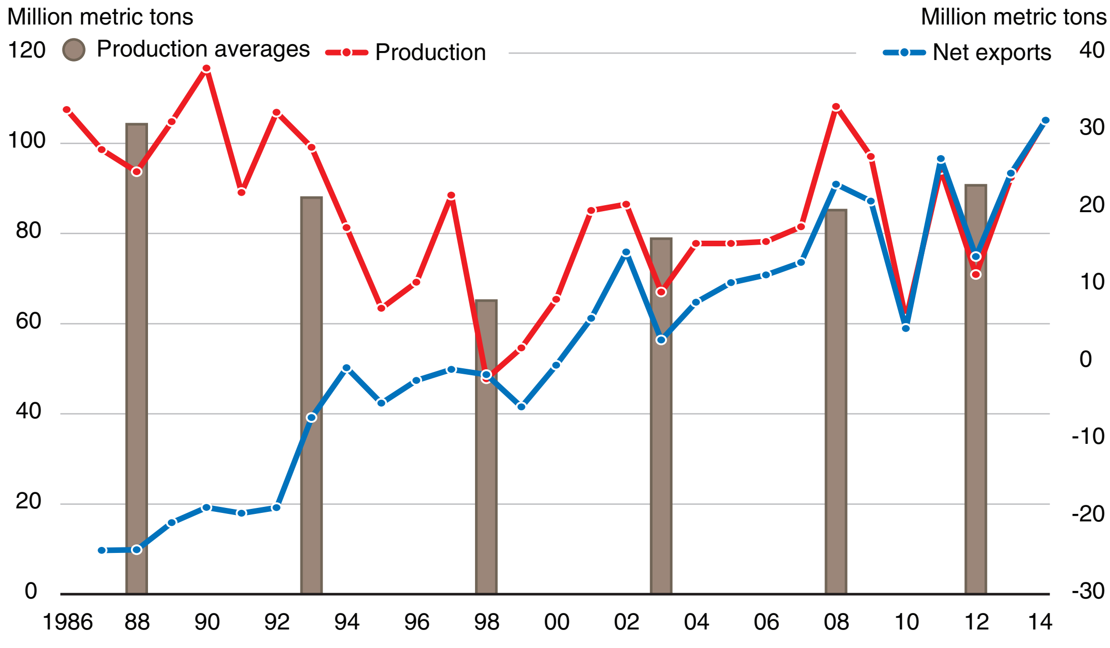
Productivity Growth and the Revival of Russian Agriculture

Introduction

Russia's move from a planned to a market economy in the early 1990s initiated a substantial contraction of the country's agricultural sector, especially its livestock subsector. Concurrently, resources used in Russian agriculture decreased considerably as the sector shed overinvestment from the Soviet era. By the end of the 1990s, total agricultural output had fallen by about two-fifths, and the production of livestock goods had dropped by half. However, the sector then rebounded; from 1998 to 2013, total agricultural output in Russia increased by about 50 percent.

Understanding the causes of Russia's agricultural revival is important as the turnaround affected not only the country's economic and rural development but also world trade. For some products, such as grain, the rise in production created surpluses for export. As grain production rose from 63 million metric tons (mmt; annual average) in 1996-2000 to 86 mmt in the 2011-14, Russian grain trade shifted from annual (average) net imports of 3 mmt to net exports of 24 mmt (fig. 1). By 2011-14, Russia supplied 7 percent of total world grain exports and 12 percent of world wheat exports.[1]

Figure 1
Russian grain production and exports



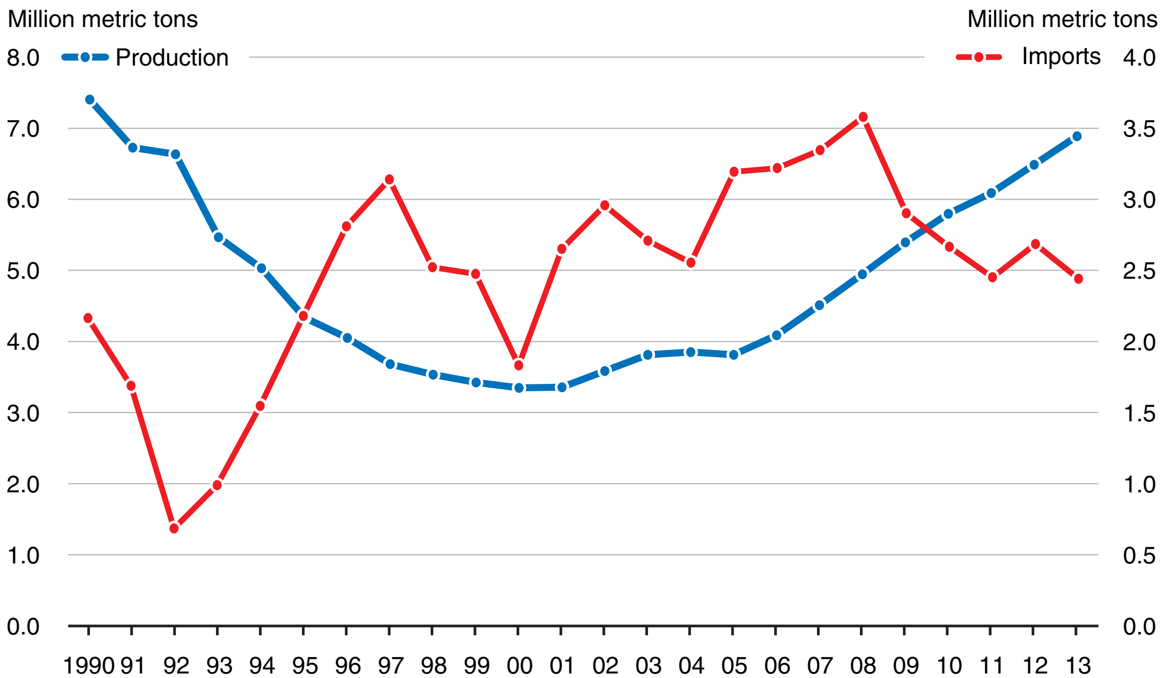
Note: The bars give average annual grain production over the periods 1986-1990, 1991-95, 1996-2000, 2001-05, 2006-10, and 2011-14. Negative net grain exports are net imports.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data and USDA, Foreign Agricultural Service, Production, Supply and Distribution database.

[1] If one groups Russia with the two other major grain-producing countries of the former Soviet Union (Ukraine and Kazakhstan), this trio accounted for 17 and 22 percent of total world exports of grain and wheat during 2011-14. In comparison, the United States supplied 21 percent of total world grain exports and 18 percent of wheat exports during the same period.

For other products, such as meat, Russia was a major importer. Following its transition to a market economy, Russia became the biggest foreign market for U.S. poultry, with U.S. exports to the country during 1995-2008 averaging 0.77 mmt a year, more than a quarter of total U.S. poultry foreign sales (USDA, 2015a). Since 2000, however, growth in Russian meat output, including a boom in poultry production, has substantially reduced the country's meat imports. Total Russian meat imports peaked in 2008 at 3.6 mmt and have since steadily declined (fig. 2). By 2013 (before Russia's current economic crisis), Russia's share of U.S. poultry exports had fallen to 10 percent (0.28 mmt).

We hypothesize that productivity growth has been a major factor in lifting Russian agriculture during the 2000s, thereby boosting grain exports and lowering meat imports. To test this hypothesis, we evaluate growth in Russia's 1994-2013 agricultural output, input, and total factor productivity (TFP) at the district and national levels, using an original dataset drawn largely from information published by Russia's Ministry of Agriculture.[2] TFP is a comprehensive measure of agricultural performance because it accounts for the contribution of all conventional inputs (land, labor, capital, materials) used in the production of farm output (crops and livestock). Specific contributions of this ERS study include application of the largest Russian agricultural database available to the literature, identification of the commodities and districts driving the rebound in Russian agricultural production, analysis of Russian input use in agriculture and its resumed growth, and evaluation and explanation of trends in national and district agricultural TFP.

Figure 2
Russian meat production and exports



Note: Both production and imports cover beef, pork, and poultry broilers.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

[2]Although Russia began its transition to a market economy immediately after gaining independence in December 1991, we chose 1994 as the first year of the analysis. This is because some of the pre-1994 data were unavailable, and the quality of some of the available pre-1994 data is suspect. By 1994, the worst of the economic disruptions inherent in the move from a planned to a market economy was largely over.

Findings reveal that over 1994-98, Russian farms decreased resource use faster than they reduced output. From 1998 to 2005, agricultural output growth rebounded nationwide but aggregate input use continued to decline. Since input use stopped declining in 2005, estimated national TFP growth averaged a modest 1.7 percent per year up to 2013. However, this national average masks important differences across Russian districts. Key to Russia's agricultural recovery has been the performance of the South district. With farms specializing in wheat, corn, vegetables, and poultry, the South district in the 2000s achieved TFP growth that exceeded the national average. Farms in the South have benefited from comparative advantages in soil and climate, geography, infrastructure, and institutions. Apart from the Central district, Russia's other districts lagged in agricultural TFP growth and weighed down the national average.

Review of Russian Agricultural Policy

The main objective of Soviet agricultural policy in the planned period years of 1970-90 was to expand the livestock sector, mainly to improve consumers' standard of living by increasing their meat and dairy consumption. With the help of substantial Government subsidies to both producers and consumers, meat production between 1970 and 1990 rose by over 60 percent (Liefert and Liefert, 2012). Soviet per capita consumption of meat and dairy products by 1990 compared favorably to that of many wealthier developed countries, even though Soviet per capita Gross Domestic Product (GDP) was less than half as much as that of those nations (Sedik, 1993).

Soviet agriculture in this era was heavily subsidized in three ways: through large budget subsidies—20 percent of the Soviet Union's entire budget went to agricultural and food subsidies during the late Soviet period (Lerman et al., 2003); through input price policy, whereby agricultural input prices were set low relative to their production cost and output prices; and through output price policy, whereby commodity prices for many products—in particular livestock goods, were set high relative to world prices. For example, in 1986, Soviet producer prices for beef and poultry were about one-fourth and two-thirds above world prices, respectively (Liefert et al., 1993).

The collapse of the Soviet Union in the early 1990s and the subsequent shift to a market economy reversed the expansion of the livestock subsector. The immediate plunge in Government revenues substantially reduced the direct budget subsidies to agricultural producers and consumers, price liberalization terminated any indirect subsidies producers received through the price system, and trade liberalization drove domestic prices downward toward world prices. The move to a market economy thereby revealed and largely eliminated the indirect price subsidies, as domestic prices for inputs and output had to adjust (for many goods substantially) and be reconciled with market demand and world market competition. These economic reforms caused output prices to fall below the real cost of producing goods, exacerbating producers' terms of trade (Macours and Swinnen, 2000; Lerman et al., 2003). Russia's domestic agricultural terms of trade (output prices relative to input prices) in this period fell by 76 percent,[3] meaning the revenue generated from a basket of agricultural products could buy on average only one-quarter of the inputs in 2000 that it could in 1990.

The large drop in direct and indirect subsidies to agriculture contributed strongly to the decrease in agricultural output, especially in the livestock subsector. Russian grain and meat production declined sharply during the 1990s, with output levels for both commodities reaching their nadir late in the decade (figs. 1 and 2). Russia's severe financial crisis in 1998 lowered GDP by 5 percent and worsened agriculture's decline as subsidies again decreased and credit tightened. Government subsidies to agriculture (in real terms, or adjusted for inflation) fell by 39 percent in 1998 and then by another 21 percent in 1999 (Russian Federal Service of State Statistics (a), 2000).[4] For context, note that in 1997, total state expenditure on agriculture equaled 10 percent of the value of agricultural output; by 1999, the figure had fallen to 6 percent.

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[3]Computed from the country's official statistics agency, the Russian Federal Service of State Statistics.

[4]Russia's 1998 financial crisis overlapped with the 1997-98 Asian financial crises, which hit countries such as South Korea, Thailand, and Indonesia, as well as Brazil and other Latin American countries. The immediate causes of Russia's crisis were the Government's default on its short-term debt and devaluation of the ruble. These events were largely driven by the drop in world energy prices (Russia being a major exporter of oil and natural gas) and a substantial increase in the Government's budget deficit in 1998 (see Liefert and Liefert, 1999).

The reduction of meat output can be viewed as a painful though necessary part of the market-driven reallocation of resources away from an overexpanded and uncompetitive high-cost subsector. Yet, the Russian Government regarded the severe contraction as a situation that needed to be reversed when feasible. It should therefore be no surprise that Russia's agricultural policy has recently returned to supporting livestock producers.[5] In 2005, the Russian Government identified agriculture as a national priority area that would receive increased funding. From 2005 to 2013, total Government budgetary support to agriculture (both federal and regional governments) rose by about 230 percent in real terms and favored the livestock subsector (Russian Federal Service of State Statistics (a), 2006 and 2014). Total state expenditure to agriculture between these 2 years rose from equaling 5.3 percent of the value of agricultural output to 9.8 percent. Moreover, some Government policies have been geared toward improving the quality of the animal-breeding stock, mainly by importing superior animals (Karlova et al., 2006). [6]

[5]Russian agricultural policy since 2000 has favored the livestock subsector over grains. For a review of Russian grain trade policy, see Liefert et al. (2013).

[6]The Russian Government also supported the livestock sector through substantial trade protection. In 2003, the federal government established a restrictive regime of tariff rate quotas for meat imports (beef, pork, and poultry), maintained with some variation to the current time. During the 2000s, Russia also imposed many sanitation-based restrictions on imports of U.S. poultry, as well as on meat imports from numerous other countries (Davis et al., 2013; Liefert and Liefert, 2012).

Emergence of a New Agricultural Producer

Three major kinds of agricultural producers have operated in Russia since the collapse of the Soviet Union: former state and collective farms—which the Russian statistical authorities call agricultural enterprises—household plots, and private family farms. Agricultural enterprises have been the dominant producer in the post-Soviet period, at least in terms of institutional structure and influence. In the early 1990s, the former state and collective farms inherited from the Soviet period were forced to reorganize. Most became corporate farms owned by their management and workers. However, on many farms, little real change occurred into the 2000s concerning internal organization, administration, and work incentives. These corporate farms remain large, averaging almost 4,000 hectares (1 hectare = 2.47 acres) in the mid-2000s (Russian Federal Service of State Statistics, 2008). In 2013, these farm types controlled 70-75 percent of the country's agricultural land and generated 48 percent of its agricultural output value, including most of the bulk crops and animal products (table 1) (Russian Federal Service of State Statistics (a), 2014).

Table 1
Russian agricultural output value shares by farm type for available years

	1990	1994	1998	2005	2013
			Percent		
Agricultural enterprises					
Total output	73.4	54.5	38.7	44.6	47.6
Crops	75.9	46.8	36.7	44	43.8
Livestock products	72	62.6	40.5	45.2	51.8
Household plots					
Total output	26.6	43.8	59.2	49.3	42.6
Crops	24.1	51	60.8	46.5	41.7
Livestock products	28	36.2	57.6	52	43.5
Family farms					
Total output	**	1.7	2.1	6.1	9.8
Crops	**	2.2	2.4	9.6	14.5
Livestock products	**	1.1	1.8	2.9	4.7

Note: ** means insignificant. Agricultural enterprises include farms that are part of agroholdings.
Source: Russian Federal Service of State Statistics (a), various years, and (b).

Households working on agricultural enterprises have retained the Soviet-era practice of maintaining small plots, with the right to consume or sell their production. The total amount of agricultural land used by these plots increased from 3 percent in 1990 to 16-20 percent by 2013 (Russian Federal Service of State Statistics (a), various years, and (b), 2009). However, this estimate includes public meadows and pastures on which the general public grazes livestock and tends garden plots. Household plots have long produced a disproportionate amount of the country's agricultural output value because they tend to specialize in the production of high-value products such as meat, fruits, and vegetables. They also have often had a symbiotic relationship with their parent farm (agricultural enterprise), through which they obtain inputs (such as animal feed) inexpensively or for free.

The third type of agricultural producer in Russia is the private family farm. These operations were created mainly by workers on corporate farms using their ownership vouchers to obtain land and break away as independent producers. By 2000, almost 300,000 family farms existed, and this number has changed little since then. In 2013, family farms accounted for 13 percent of all land use in Russia and nearly 10 percent of agricultural output by value (table 1). Like agricultural enterprises (corporate farms), family farms in Russia specialize in the production of bulk crops, such as grain and sunflower seed.

In the Soviet planned economy, farms did not have decisionmaking power over their input use and output mix; rather, farms received from central planners a specific allocation of inputs tied to mandated output targets. Farms faced no competitive market pressure to be efficient, reduce waste, and economize on inputs. In Russia's market economy, however, farms not only have the potential to earn profit but are required to be largely self-financing. They have new decision-making freedom, including choice of output and input mix, and stronger managerial control to improve labor incentives.[7]

Starting around 2000, as Russia became more integrated into the world agricultural economy, international trade, foreign agricultural investment, and technology transfer expanded. Much of the new agricultural technology imported by Russia has come in the form of superior Western machinery, seeds, and animal stock (Karlova et al., 2006; Interfax, multiple issues). In particular, Russia has become a major importer of hybrid corn seed from the West (mainly EU countries, such as France and Hungary), which has helped to drive Russia's expansion of corn production. From 2002 to 2015, Russian imports of corn seed rose from 5,697 tons to 36,820 tons (Global Trade Atlas, 2016), with imports in 2015 accounting for 50 percent of total corn seed used for planting that year (USDA, 2015b). During this same period, Russian corn yields increased from 2.83 tons per hectare to 4.93 tons per hectare. Imported seeds have also contributed to rising sunflower seed yields.

It would be expected that many producers would respond to these new market opportunities and decisionmaking freedoms in ways that would improve the efficiency of their operations. Around the year 2000, a different type of agricultural enterprise emerged. Dubbed by Rylko et al. (2008) as "new operators," these farms appear to have responded positively to these new prospects. A particular class of these new operators is the very large agroholdings. The agroholdings acquire existing corporate farms and vertically integrate them, combining primary production, processing, distribution, and sometimes retail sales (Gataulina et al., 2005; Serova, 2007; Rylko et al., 2008).

Advantages that agroholdings wield over other farming operations include lighter constraints on credit and liquidity (e.g., by pooling collateral they reduce banks' lending risk, which reduces the applied interest rate) and a greater emphasis on managerial and staff training (Gataulina et al., 2005; FAO, 2009). Serova (2007) argues that agroholdings have brought much-needed capital investment to modernize the Russian agricultural sector.

However, the literature is unclear whether agroholdings represent the current best production practice in Russian agriculture. Rylko et al. (2008) find that Russian agroholdings have higher land and labor productivity than other Russian agricultural producers. Other anecdotal evidence supports the argument that agroholdings tend to outperform their competition (FAO, 2009; Interfax). On the other hand, Gataulina et al. (2005) and Hockmann et al. (2009) find that agroholdings are not more productive or profitable than other large Russian agricultural enterprises. Each of these studies,

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[7]In the Soviet planned economy, prices and markets were not used to allocate inputs and output for farms and industrial enterprises. However, goods were given cost-based prices, largely for accounting purposes (such as in aggregating output across products and industries).

though, uses a limited set of survey data. Resolving this dispute will require empirical evidence from nationally representative farm-level or farm-type data.

Agroholdings developed, in part, as a response to the market and infrastructural (physical, commercial, institutional) deficiencies faced by Russian farms (Deininger and Byerlee, 2012). For example, input suppliers on one side and the wholesalers and processors on the other are typically large and concentrated and can use their market power vis-à-vis farms to determine the prices at which they sell to and purchase from farms (for concentration among suppliers, see Serova and Shick, 2008). The agroholdings' size and vertical integration help insulate them from these problems and help to reduce the high transaction costs posed by such market imperfections (Svetlov and Hockmann, 2009; Davydova and Franks, 2015).[8] Some studies, though, have countered that agroholdings have become so large and unwieldy that they suffer from diseconomies of scale (Gataulina et al., 2005; Wandel, 2009).

What is clear from the literature is that these large, vertically integrated producers have a strong presence in Russia's South district and have been instrumental in the ongoing output specialization detailed in the section that follows. For example, agroholdings have been the driving force behind Russia's booming poultry industry, which over the period 2000 to 2013 raised broiler output from 0.41 to 3.01 million tons.

[8]Russian agricultural producers face high transaction costs not only in their commercial farming operations but also in land acquisitions. Although land in Russia can be bought and sold, many institutional-type impediments exist to such transactions. These include a multitude of regulations concerning such matters as land-plot partition and surveying, document preparation, and registration of sales. These obstacles particularly hurt smaller producers such as the private family farms, and give new operators and agroholdings a relative advantage in that they can more easily cover these costs from their large operations and have the legal capacity to handle the complicated regulations and procedures (Shagaida and Lerman, 2017).

The Restructuring of Russian Agricultural Output and Input Use

To investigate Russia's agricultural performance at the district and national levels and over the 1994-2013 period, we employ a new agricultural production dataset covering Russia's 77 regions. These data are used to detail the changing structure of Russian agricultural output and input use and to provide context for the subsequent TFP growth estimates. This ERS study employs data drawn mainly from Russia's Ministry of Agriculture publications, though also partly from the Russian Federal Service of State Statistics.[9] From these sources, we construct the largest Russian agricultural production account available to the literature. In doing so, we bring new information to bear on the question of Russia's agricultural growth. Other studies on agricultural production in Russia employ digitized data from the Food and Agricultural Organization of the United Nations (FAO) (Cungu and Swinnen, 2003; Swinnen and Vranken, 2010; Swinnen et al., 2012) or the Russian Federal Service of State Statistics (Goskomstat) (Sedik et al., 1999; Lerman et al., 2003; Osborne and Trueblood, 2006; Voigt and Hockmann, 2008; Bokusheva et al., 2012; Belyaeva and Hockmann, 2015). The data used in these previous studies either lack a subnational dimension or provide limited detail on important inputs, such as fertilizer.

All regional statistics are aggregated into the same seven districts employed by the Russian Federal Service of State Statistics and to the national level (fig. 3).[10] The Central, Northwest, South, and Volga districts are all in European Russia and are divided from the remaining districts by the Ural Mountains, which are roughly located on the western border of the Ural district.[11]

Agricultural Output

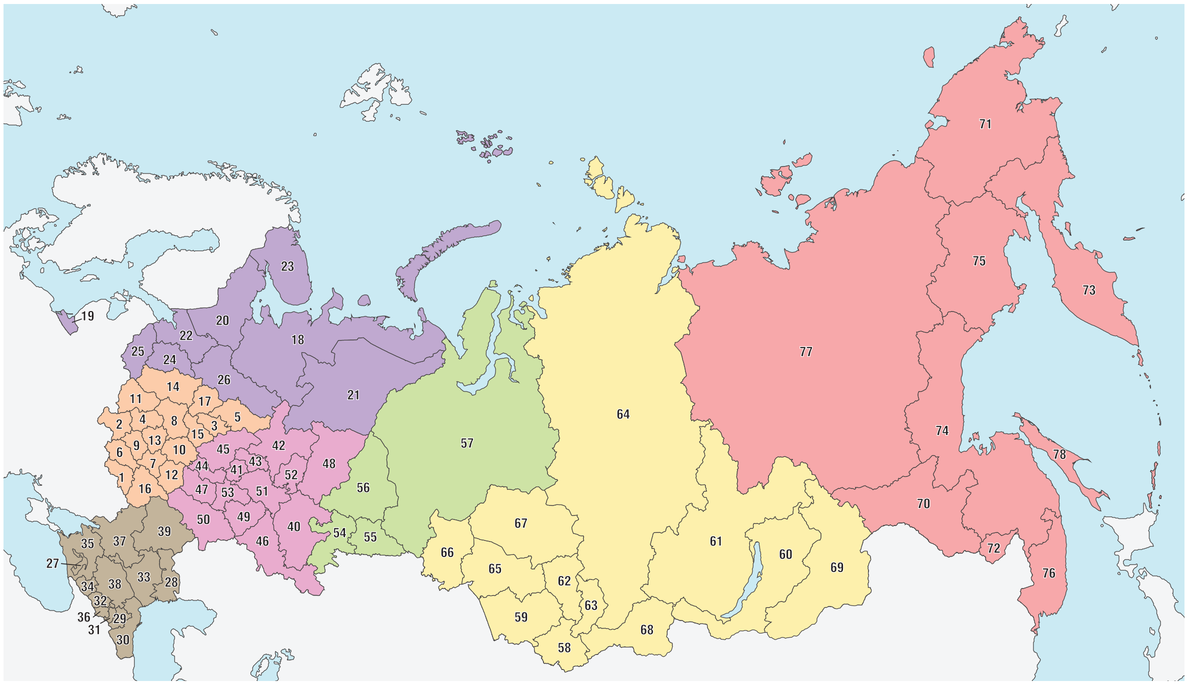
The commodities examined in this study include grains, sunflower seed, sugar beets, potatoes, vegetables, flax, meat, milk, and eggs. These outputs, on average over 1994-2013, accounted for 94 percent of Russia's estimated total gross agricultural value (FAO, 2016). As discussed earlier, in the Soviet planned economy, central planners determined input use and output mix for farms. In addition, rather than concentrating production based on specialization as they generally did for industry, Soviet planners pursued regional self-sufficiency for agriculture; that is, regions produced a range of products that largely satisfied local consumption needs. Unlike in a market economy, cost minimization and comparative advantage in the Soviet system were much weaker determinants of regional agricultural production. The policy of nonspecialization was also adopted for individual farms (which were large during the Soviet period), which tended to produce an array of products (Gregory and Stuart, 1987).

[9]The appendix to this ERS report presents information as to how the output and inputs are measured, and appendix table 1 provides data sources.

[10]Russia's 77 administrative units (what we call *regions* in this report) can be translated from Russian as regions (oblasts), republics, or territories. The Russian word for *district* used in statistical publications is okrug.

[11]To help with orientation, note that Russia's capital Moscow lies within the Moscow region (8 in fig. 3) in the Central district, while St. Petersburg lies within the Leningrad region (22 on the map) in the Northwest district. Also, in 2011, the Russian Federal Service of State Statistics in its publications divided the South district in two: a newly created North Caucasus and the South, with the latter retaining those regions that were not moved into the North Caucasus. However, in this ERS report through 2013 (the end year of our empirical analysis), the South district covers all the regions included in the South in Russian statistical publications up to 2010.

Figure 3
Map of the Russian Federation



Federal Districts

Central
1 Belgorod
2 Bryansk
3 Ivanovo
4 Kaluga
5 Kostroma
6 Kursk
7 Lipetsk
8 Moscow
9 Orel
10 Ryazan
11 Smolensk
12 Tambov
13 Tula
14 Tver
15 Vladimir
16 Voronezh
17 Yaroslavl

Northwest
18 Arkhangelsk
19 Kaliningrad
20 Karelia
21 Komi
22 Leningrad
23 Murmansk
24 Novgorod
25 Pskov
26 Vologda

South
27 Adygea
28 Astrakhan
29 Chechnya
30 Dagestan
31 Ingushetia
32 Kabardino-Balkaria
33 Kalmykia
34 Karachay-Cherkess
35 Krasnodar
36 North Ossetia
37 Rostov
38 Stavropol
39 Volgograd

Volga
40 Bashkortostan
41 Chuvash
42 Kirov
43 Mari-El
44 Mordovia
45 Nizhny Novgorod
46 Orenburg
47 Penza
48 Perm
49 Samara
50 Saratov
51 Tatarstan
52 Udmurt
53 Ulyanovsk

Ural
54 Chelyabinsk
55 Kurgan
56 Sverdlovsk
57 Tyumen

Siberia
58 Altai Republic
59 Altai Territory
60 Buryat
61 Irkutsk
62 Kemerovo
63 Khakassia
64 Krasnoyarsk
65 Novosibirsk
66 Omsk
67 Tomsk
68 Tuva
69 Zabaikal

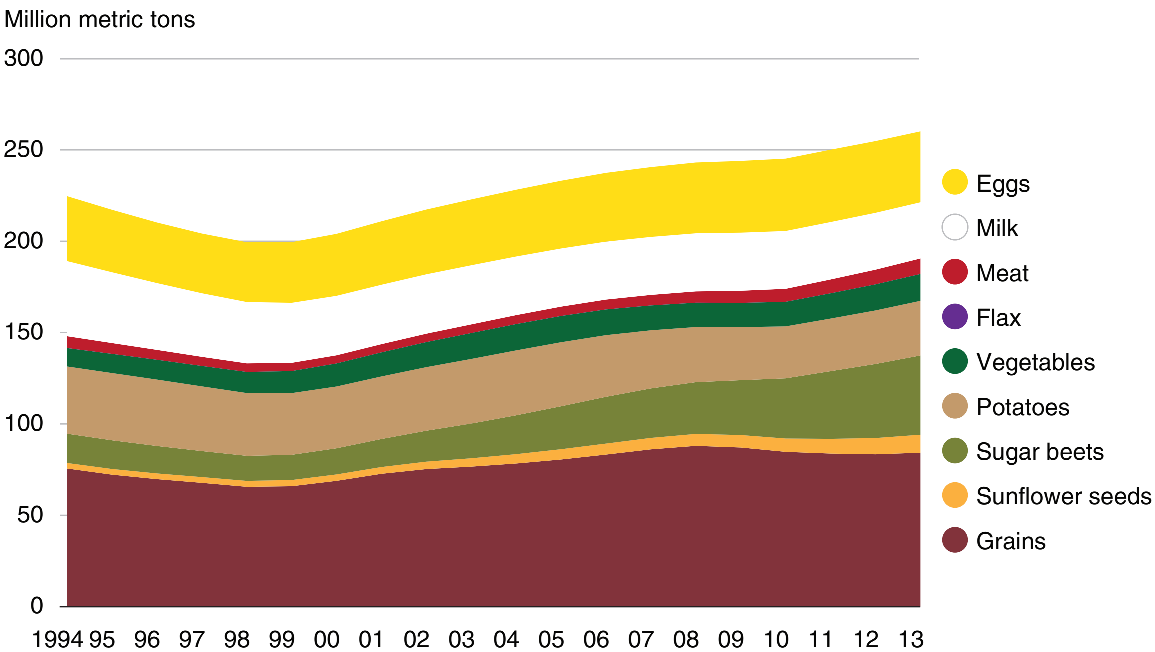
Far East
70 Amur
71 Chukotka
72 Jewish Autonomous State
73 Kamchatka
74 Khabarovsk
75 Magadan
76 Primorsky
77 Sakha
78 Sakhalin

Source: USDA, Economic Research Service.

During the 1990s, Russian agricultural production contracted severely and then began to rebound in the late 1990s. In particular, after 1998, national production increased for grains, sunflower seed, sugar beets, vegetables, and eggs but continued to decrease for potatoes, flax, and milk (fig. 4). During 1994-2013, sunflower seed and sugar beets had the highest average annual average growth by volume at 6.5 percent and 6.1 percent, respectively. Both of these crops were produced in relatively low volumes early in the reference period.[12] On a national level, average annual production growth during the period was modest for grains (1.4 percent), somewhat higher for vegetables (1.6 percent) and meat products (2.3 percent), and somewhat lower for eggs (1.1 percent). Average annual production volumes for milk, flax, and potatoes declined by 1.0 percent, 0.3 percent, and 1.4 percent, respectively. Rising production of meat, grain, and sunflower seed reflects the major Russian agricultural commodity developments since the late 1990s: the revival of the livestock sector and Russia's emergence as a major grain exporter, with the additional grain output either exported or used as animal feed (along with the (crushed) sunflower seed).

If we include output prices, a newly important determinant of farm output choice, we can confirm that the composition of Russian agricultural production shifted over 1994-2013.[13] Among commodities examined, meat had the highest annual average revenue share (27 percent) during the period despite the large contraction of the livestock subsector during the 1990s. Notably, by 2009-13, the meat share of Russia's total agricultural revenue climbed to 32 percent (fig. 5). The revenue shares of sunflower seed and vegetables also rose over the period, while that of potatoes declined substantially.

Figure 4
Russia's recovering agricultural production volumes

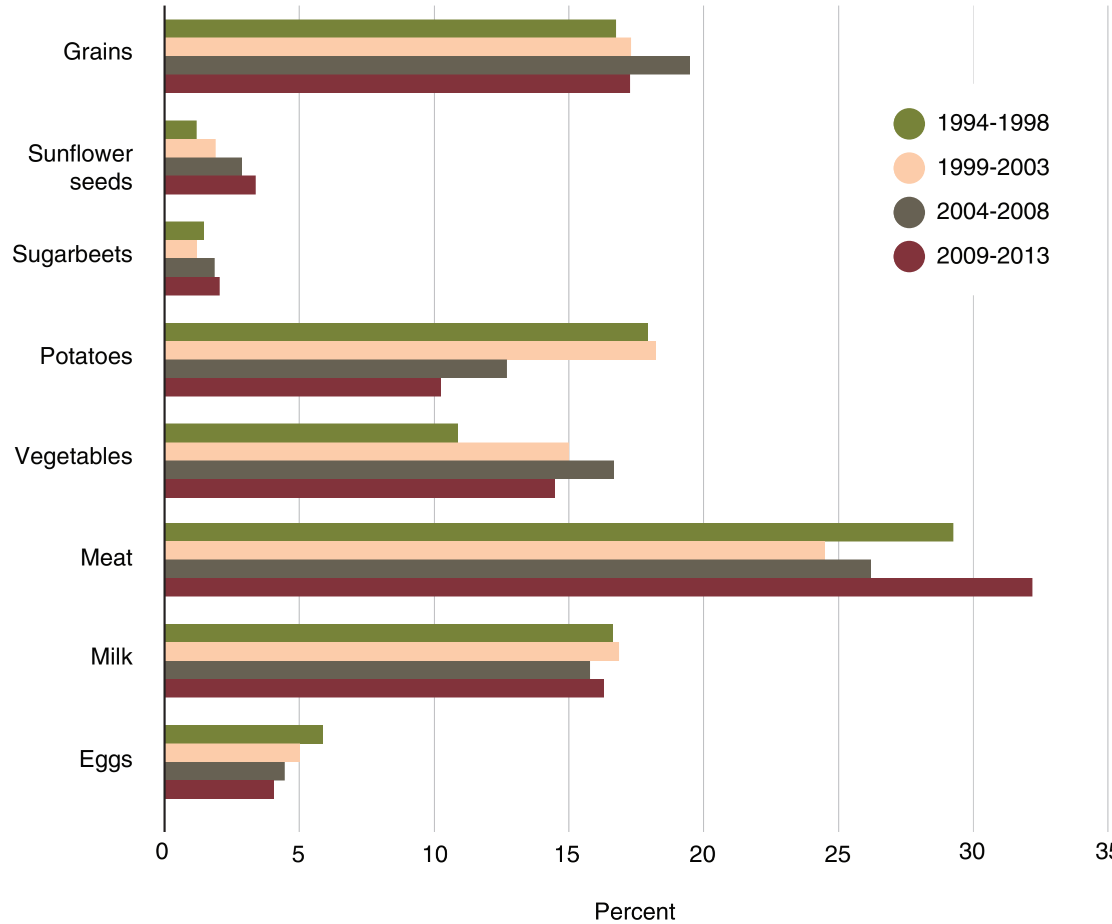


Note: Data have been smoothed by Hodrick-Prescott filter; lambda = 6.25. Flax is included in the figure for completeness, but its values are unseen.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

[12]Although Russia produces soybeans and rapeseed, sunflower seed is the country's dominant oilseed. It is also the only oilseed for which regional output data are available throughout the 1994-2013 period.

[13]National prices are used throughout the report because regional and district-level prices are not available.

Figure 5
Russia's shifting agricultural revenue shares, by 5-year period



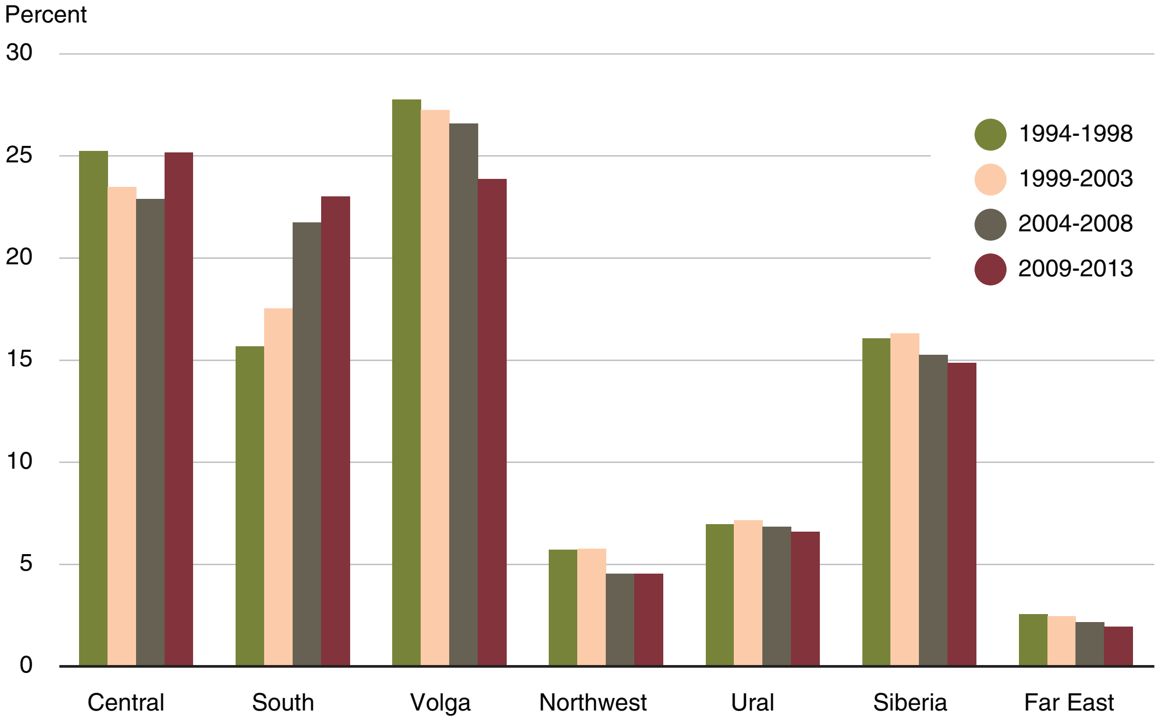
Note: Flax's revenue shares have been omitted due to low values. They are, by respective periods: 0.03 percent, 0.04 percent, 0.03 percent, and 0.03 percent.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

Despite volume growth for grains since 2000, the crop's revenue share was only marginally higher in 2009-13 than in 1994-98.

The geographic structure of Russian agricultural output has also changed significantly, which largely reflects the move away from the Soviet policy of regional nonspecialization. The main development during 1994-2013 was rising production in the South district. Indeed, the South was unique among Russian districts for having increased its share of national agricultural revenue from 16 percent in 1994-98 to 23 percent in 2009-13 (fig. 6). By 2009-13, the Central district had recovered the 25-percent revenue share it lost in 1994-98. The Volga district, which had the highest revenue share among districts in the 1990s and early 2000s, experienced a similar but stronger decline in its share than did the Northwest, Ural, Siberian, and Far East districts.

Farm operators in the South district have benefited from the newfound flexibility to choose their output mix (fig. 7). For example, wheat and corn output have grown rapidly in the South since 2000. Among all districts, the South is a leader in the production of corn and sunflower seed, two important components of animal feed, and is the top producer of grains and vegetables. These production decisions likely reflect the rise of vertically integrated agroholdings that combine

Figure 6
Russian South district's unique rise in share of agricultural revenue, by 5-year period



Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

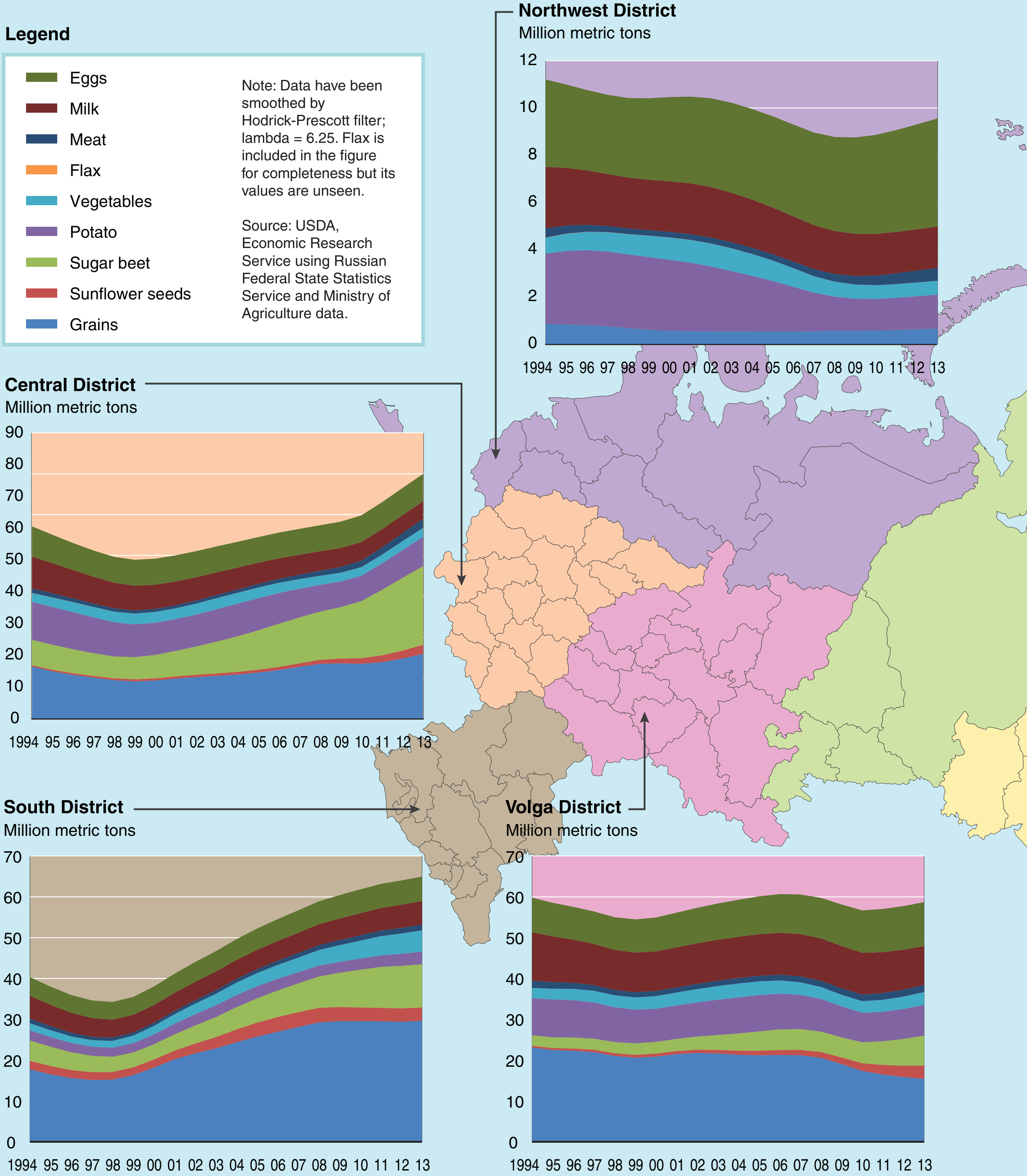
grain and oilseeds production with livestock production to safeguard feed supplies (Deininger and Byerlee, 2012).

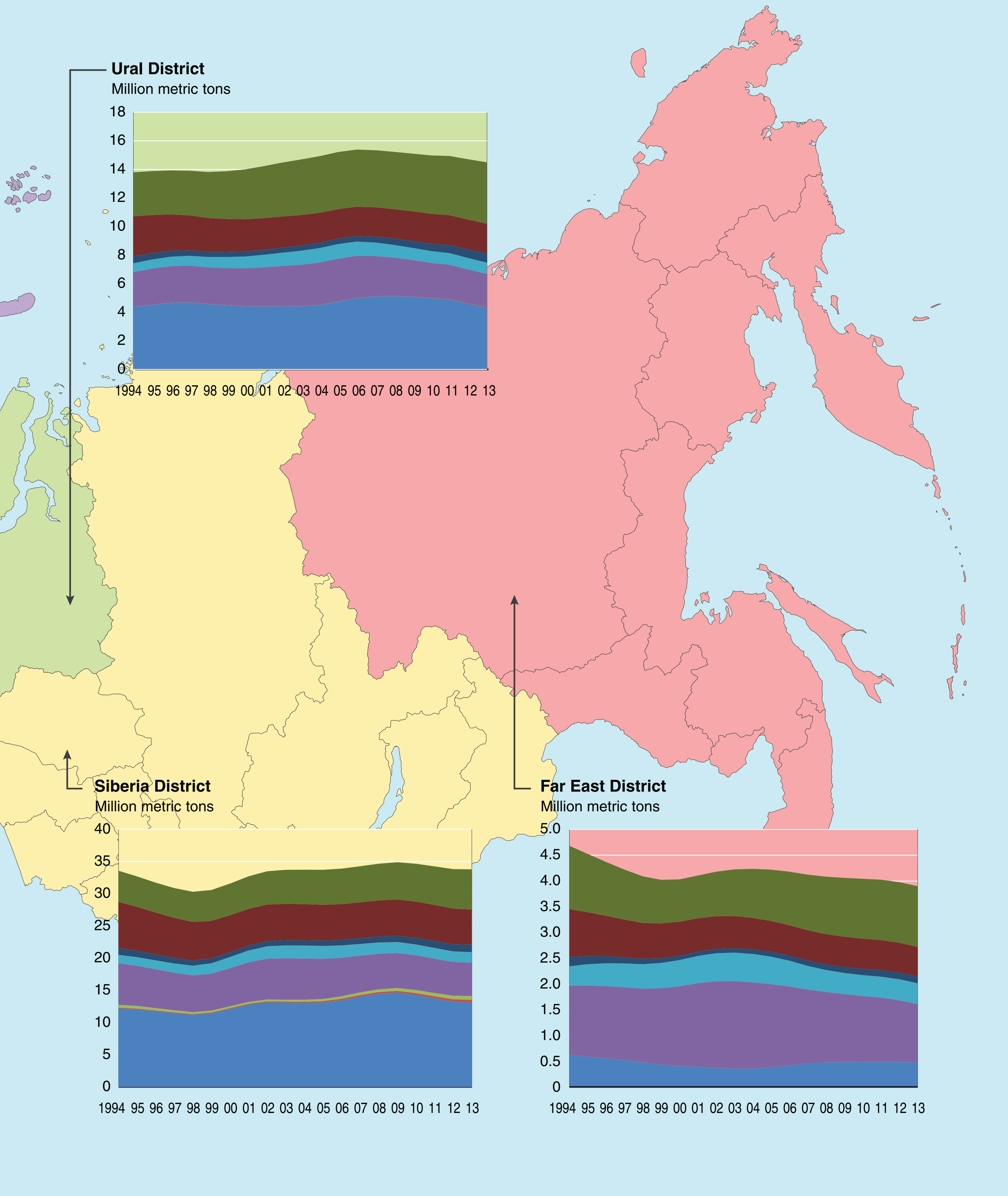
The Central Russian district has long been the country's top producer of sugar beets and potatoes. Reflecting the opportunity to adjust output composition, operators in the Central district have increased sugar beet production and decreased potato production (fig. 7). In 2009-13, farms in this district produced 56 percent of national sugar beet output, more than doubling production of the second-largest producer (the South). Wide swings in year-to-year rainfed grain production make it difficult to discern whether there has been any long-term rise in grain output in the Central district. Smoothing the data using the Hodrick-Prescott filter to eliminate short-term fluctuations from long-term trends produces results that suggest grain production has rebounded in the district and recently exceeded 1994 levels.

The Volga, third among Russia's large agricultural producing districts, has shifted from grains, potatoes, and milk toward sugar beets, eggs, and sunflower seed (fig. 7). However, the district continues to be the country's top milk producer and has become the top egg producer. In the early 1990s, the Volga was Russia's largest grain producer, but declining production has moved it behind the Central and South districts in this category. Part of that decline was due to specialization in rye production during the Soviet period. A national shift away from rye production has thus disproportionately affected producers in the Volga.

The remaining districts—Northwest, Ural, Siberia, and Far East—have all marginally improved, stagnated, or reduced aggregate agricultural production during the period of analysis; by 2009-13, they accounted for a combined 28-percent share of national agricultural revenues (fig. 7). Since

Figure 7
Russia's changing agricultural output composition by district, 1994-2013



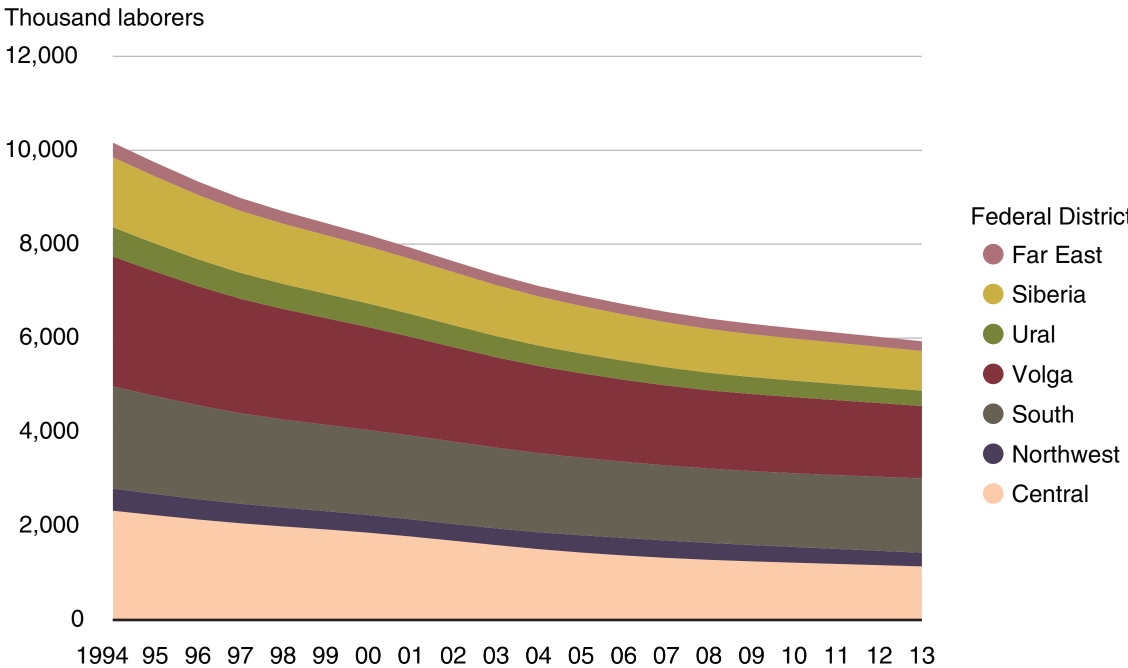

Ural District
Million metric tons
18
16
14
12
10
8
6
4
2
0
1994 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13
Siberia District
Million metric tons
40
35
30
25
20
15
10
5
0
1994 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13
Far East District
Million metric tons
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
1994 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13

1999, all four districts have expanded production of meat and eggs while reducing production of potatoes. Reflecting their locations in the extreme northern and eastern parts of the country, which are characterized by less favorable soil and climate, the Northwest and Far East districts have deepened their specialization in livestock products (meat, milk, and eggs) and produce little grain, sunflower seed, or sugar beets.[14]

Labor Inputs

Similar to most of Russia's other factors of agricultural production, the number of farmworkers in Russia has declined steadily since the early 1990s, dropping from 10.3 million in 1994 to 5.9 million in 2013, or 2.9 percent per year (fig. 8). The speed at which labor exited agriculture has varied by district. The districts with the largest labor supply in 1994 were the South, Central, and Volga, and the Volga and Central have had the greatest labor losses among all districts over time. The Central and Volga districts accounted for half of national farm labor in 1994, and each lost at least 3 percent of its labor each year. In light of the agricultural production trends noted earlier, it is unsurprising that the South had the slowest farm labor decline (1.7 percent each year) among all districts. In fact, from 2008 to 2013, the South's farm labor exodus mostly stopped (0.25 percent decline per year).

Figure 8
Falling agricultural labor across Russian districts



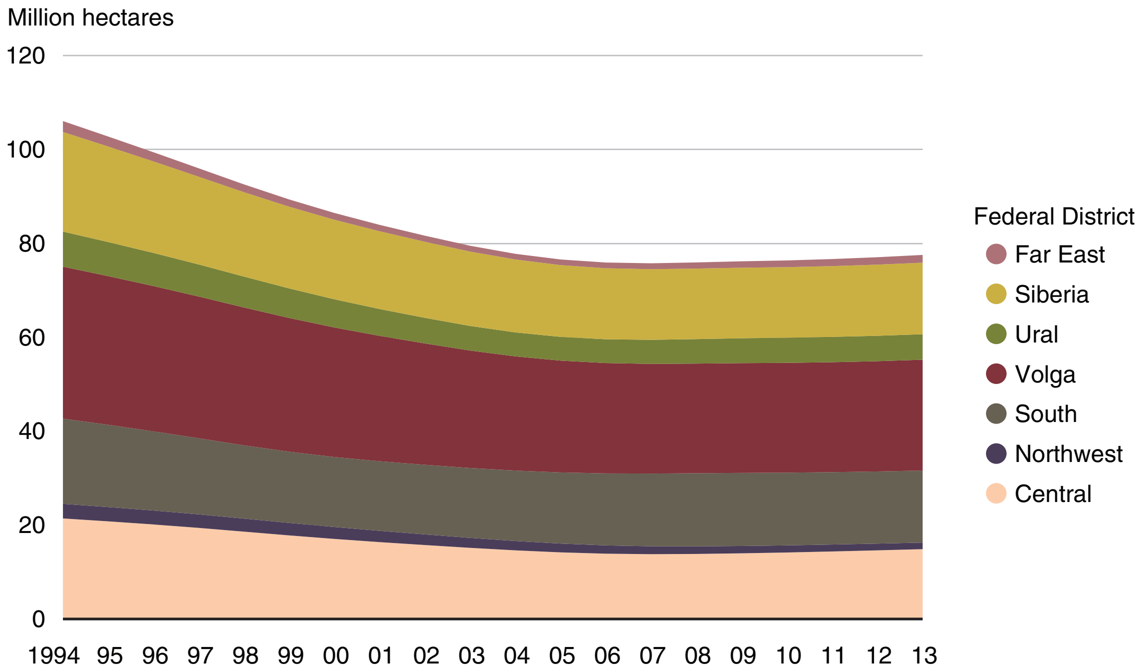
Note: Data have been smoothed by Hodrick-Prescott filter; lambda = 6.25.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

[14]Liefert and Liefert (2015) show that, although regions in the northern and eastern parts of Russia were not large grain producers during the Soviet period, they have since decreased their grain acreage and output by a greater proportion than have other regions, mainly because of higher production costs than regions more favorably endowed for grain production. This demonstrates the economically inefficient Soviet policy of pushing agricultural production (such as for grain) into high-cost regions.

Land Inputs

Sown area in Russia fell from 105 million hectares in 1994 to 78 million hectares in 2013, or by 1.7 percent per year on average (fig. 9). National sown area declined by 2.8 percent each year from 1994 until 2007 when it reached its nadir. It then gradually edged upward until 2013, rising 0.3 percent per year. The recent increase was primarily in the Central district, which added 1.5 million hectares between 2007 and 2013, or 1.5 percent per year. The Volga, Ural, Siberian, and Far East districts have also expanded sown area since 2007, though their gains were much smaller than those of the Central district and ranged from 210,000 hectares in the Volga to 428,000 hectares in the Far East. The South district reached its land-use nadir in the year 2000—much earlier than in other districts. Sown area in the South fell from 17.9 million hectares in 1994 to 14.6 million in 2000 and then slowly rose to 15.5 million hectares by 2013. The South's low growth rate of area since 2000 (0.4 percent per year) contrasts with its much faster growth rate of output (see fig. 7), indicating a rise in aggregate crop yield.

Figure 9
Leveling off of sown area by Russian district



Note: Data have been smoothed by Hodrick-Prescott filter; lambda = 6.25.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

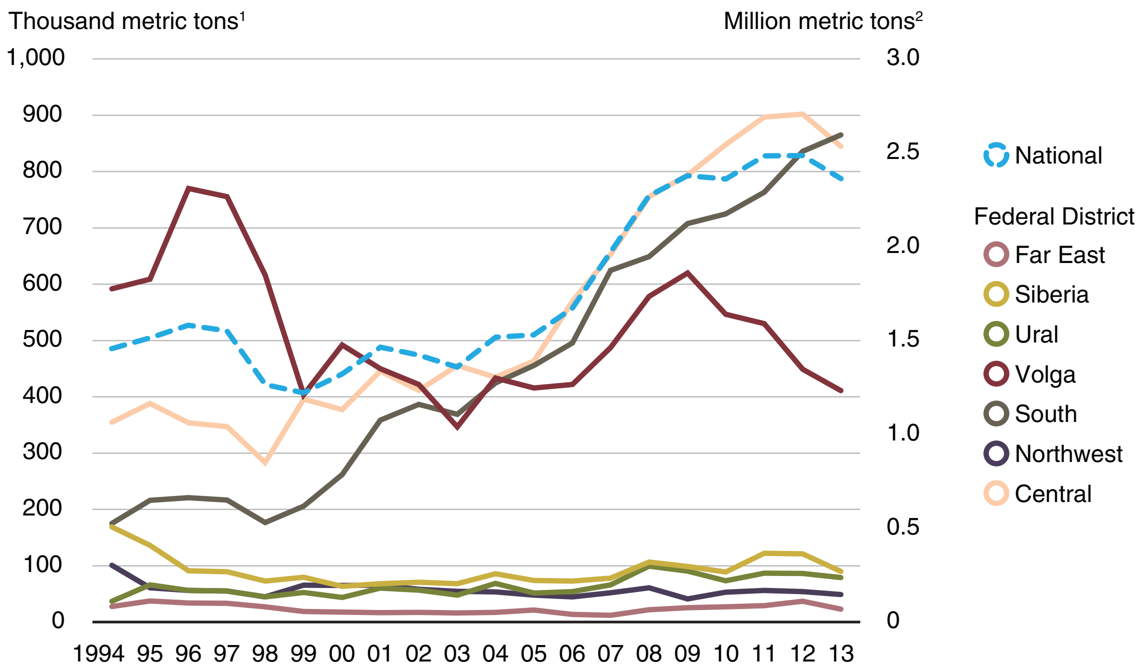
Material Inputs

Material inputs in agriculture consist of seed, fertilizer, machinery fuel, and feed. Seed information is largely unavailable from Russian sources. As noted earlier, imported seed varieties have boosted corn yields. Russian fertilizer use fell substantially during the early 1990s, mainly because the price of fertilizer rose substantially relative to crop output prices as part of the extreme worsening of agricultural producers' domestic terms of trade. Between 1994 and 2005, fertilizer use grew modestly but dropped in 1998 due to a crimp in supply. However, between 2005 and 2013, it increased by 5.7 percent each year. The South and Central districts accounted for most of that growth (fig. 10).

Machinery fuel consists of diesel and gasoline. Russian farms use about double the amount of diesel fuel as gasoline, although uses of both types have fallen since 1994. While national diesel use steadied after the 1998 economic crisis, gasoline use continued to slowly decline. Though all districts experienced declining machinery fuel use up to the 1998 crisis, only the South achieved period-average increases in total fuel use.

Feed data for animal inventories are available for agricultural enterprises only. Historically, the Volga has been Russia's dominant feed-consuming district, which is consistent with the Volga's specialization in meat products. The South was Russia's second-largest feed consumer during 1994-99, surpassed the Volga in 2007, and remains in the top position as of 2013. The available feed data, paired with the livestock capital information presented in the next section, suggest that the rising feed inputs in the South district are primarily for poultry production. The symbiotic relationship between private plots and agricultural enterprises discussed earlier affords the assumption that some inputs, such as feed, that are supplied to agricultural enterprises are used by private plots, which otherwise have little access to such resources.

Figure 10
Increasing fertilizer use in some Russian districts



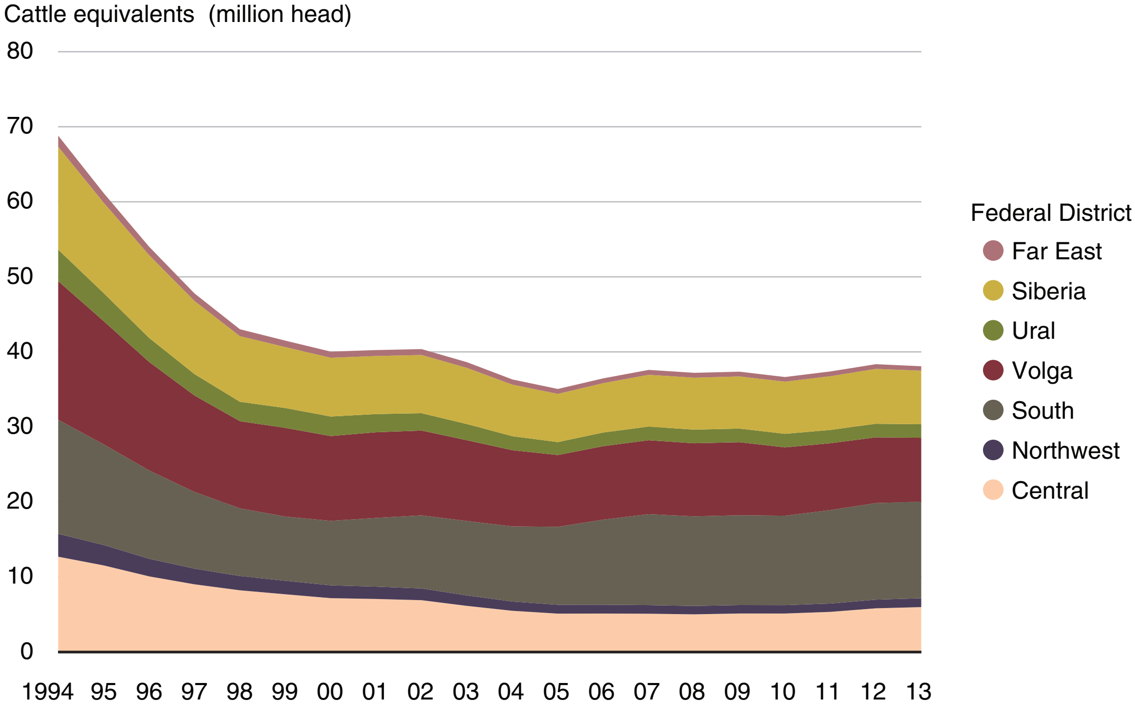
[1]District data. [2]National data.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

Capital Inputs

Capital inputs consist of livestock and machinery capital. Livestock capital accounts for the onfarm stock of animals and includes cattle, sheep, goats, pigs, and poultry. Russian livestock numbers fell heavily (12 percent per year) from 1994 to 1998, declined at a lower rate (3 percent per year) to 2005, and then rose slightly (1 percent per year) to 2013 (fig. 11). Almost all the growth in Russian animal

Figure 11

Changing geography of Russia's livestock capital



Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

stocks since 1998 was in the South. The composition of Russia's animal stocks changed as well. Cattle inventories have continuously decreased since 1994. Pig inventories declined until about 2005 and have since increased, though by 2013, they were still below their 1994 level. Sheep and goat inventories rebounded in 2000, but by 2013, they also had not yet returned to their 1994 levels. Alone among the animal stocks, poultry inventories by 2013 surpassed their 1994 level.

Machinery capital covers the number of in-use tractors, grain harvesters, and sugar beet harvesters. On average over the 1994-2013 period, the Volga and Central districts accounted for half of all machinery stocks in Russia, and the South accounted for 18 percent. Producers rapidly shed overinvestment in machinery capital following the country's shift to a market economy. In 1994, there were 2 million tractor-equivalent machines in use on Russian farms. By 2013, there were only 468,000, an 8.1-percent decline on average each year. Machinery stocks decreased rapidly and rather evenly across all districts; district shares of national machinery capital have mostly remained steady over the study period. The lone exception is the South district, which slowed its machinery capital losses sooner than other districts and thus increased its share of total machinery capital. The South's rise in fuel use after 1998 is not entirely consistent with the long-term decline in machinery capital. Such inconsistency may indicate increased usage per machine or the presence of unmeasured machinery capital on Southern farms.

Evaluating Russia's Agricultural Performance

Agricultural TFP studies of Russia have focused on either multicountry comparisons (Lerman et al., 2003; Cungu and Swinnen, 2003; Swinnen and Vranken, 2010; Swinnen et al., 2012) or subnational comparisons of relative technical efficiency (Sedik et al., 1999; Osborne and Trueblood, 2006; Voigt and Hockmann, 2008; Bokusheva et al., 2012; Belyaeva and Hockmann, 2015). A common finding among the efficiency studies is positive national TFP growth following the 1998 Russian financial crisis, which was composed of divergent regional growth and driven initially by improved domestic terms of trade and later by regional comparative advantages. Absent from the literature, though, is identification of districts that were most productive and the commodities in which they specialized. This ERS study fills those gaps in the literature and in doing so provides the necessary interpretations of Russia's TFP growth estimates as a measure of agricultural performance.

Clarifying Russia's Agricultural Performance

We find that Russia's 1994-2013 annual agricultural TFP growth, defined as the difference between aggregate output growth and aggregate input growth, averaged 3.5 percent.[15] But in light of the resource loss detailed earlier, it is unclear whether this strong TFP growth rate was mainly the result of declining input use or improved agricultural technologies and efficiencies. To help determine the driving factor, we characterize Russia's long-term agricultural TFP growth by period.

Three distinct periods emerge when evaluating Russia's agricultural TFP growth: (1) 1994-98; (2) 1998-2005; and (3) 2005-13 (fig. 12). Between 1994 and 1998, Russia's aggregate input use declined at nearly twice the rate (8.8 percent, annual average) of output (down 4.6 percent, annual average), leading to positive TFP growth of 4.2 percent.[16] Yet this rapid rate of TFP growth simply reflects the process of downsizing agriculture to a level compatible with a market economy, compared with the costly and overexpanded agricultural sector determined by Soviet planners using large subsidies.

In the second period (1998-2005), output growth rebounded to 3.1 percent (annual average) while input growth continued to fall by 2.3 percent, which raised annual average TFP growth to 5.4 percent. We find the 1998 national output growth recovery was largely a reflection of activities in the South. While each Russian district experienced the same downward trend leading up to the 1998 economic crisis, the depth of those production losses—and subsequent recovery—varied widely by district (fig. 13). The South experienced the largest output drop between 1994 and 1998, followed by the Siberian and Central districts. However, the South also achieved the largest output gains after 1998, averaging over 5 percent growth each year to 2013. The output growth achieved by the South stands apart from other districts by its early and sharp rebound. Therefore, caution is urged when interpreting the rapid average annual growth rate (5.4 percent) of national TFP during 1998-2005 as a measure of national agricultural performance. On average across regions, input use continued to decline as the sector had not yet finished shedding resources, and with the key exception of the South, output growth in districts that managed to generate any gain in production whatsoever was slight.

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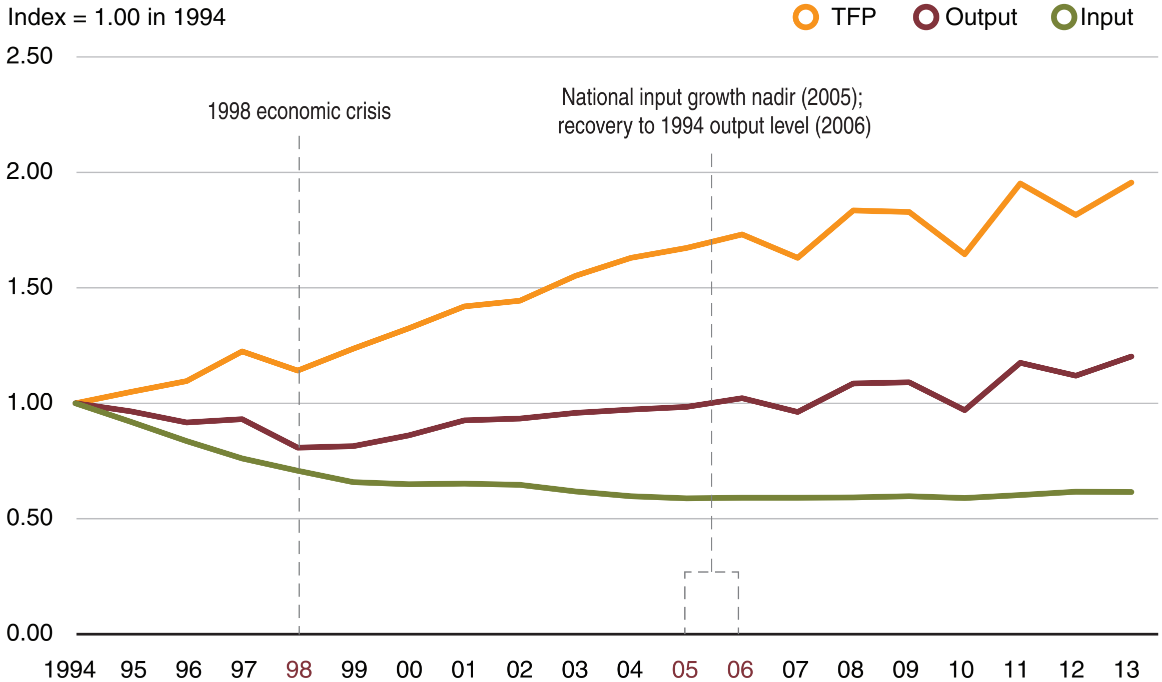
[15]For technical details on how TFP is estimated, see the appendix.

[16]As mentioned earlier, this output decline was a continuation of the drop that began with the collapse of the Soviet Union in 1991.

Figure 12

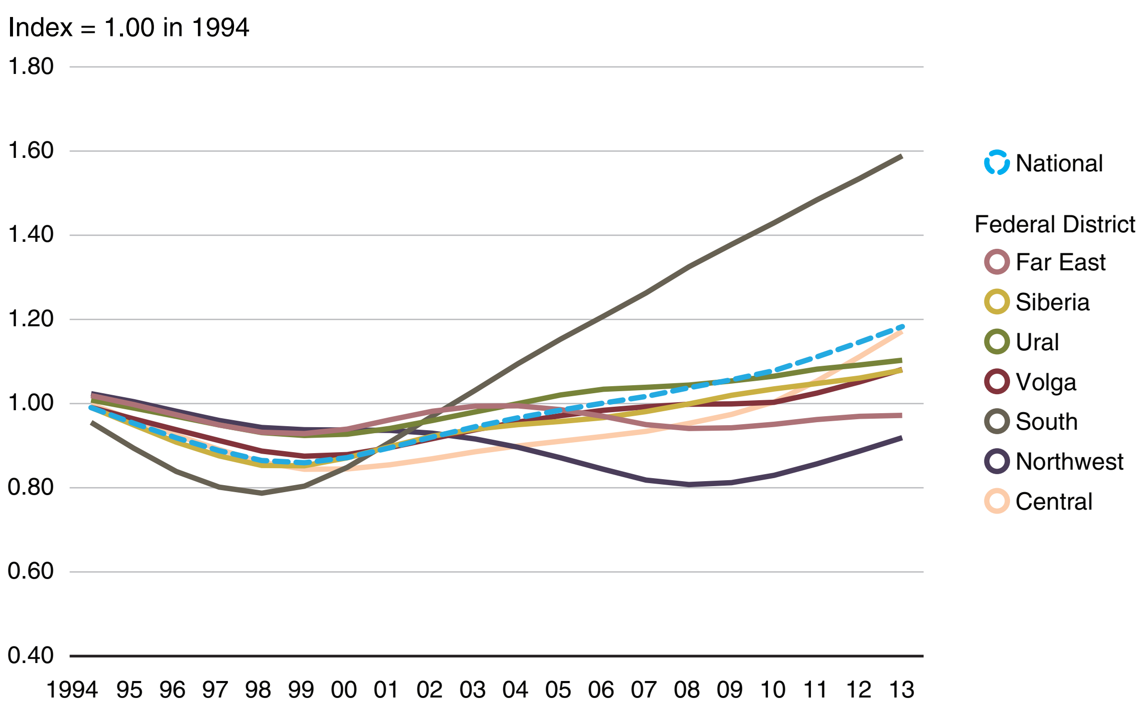
Russia's agricultural TFP growth



TFP = Total factor productivity.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

Figure 13

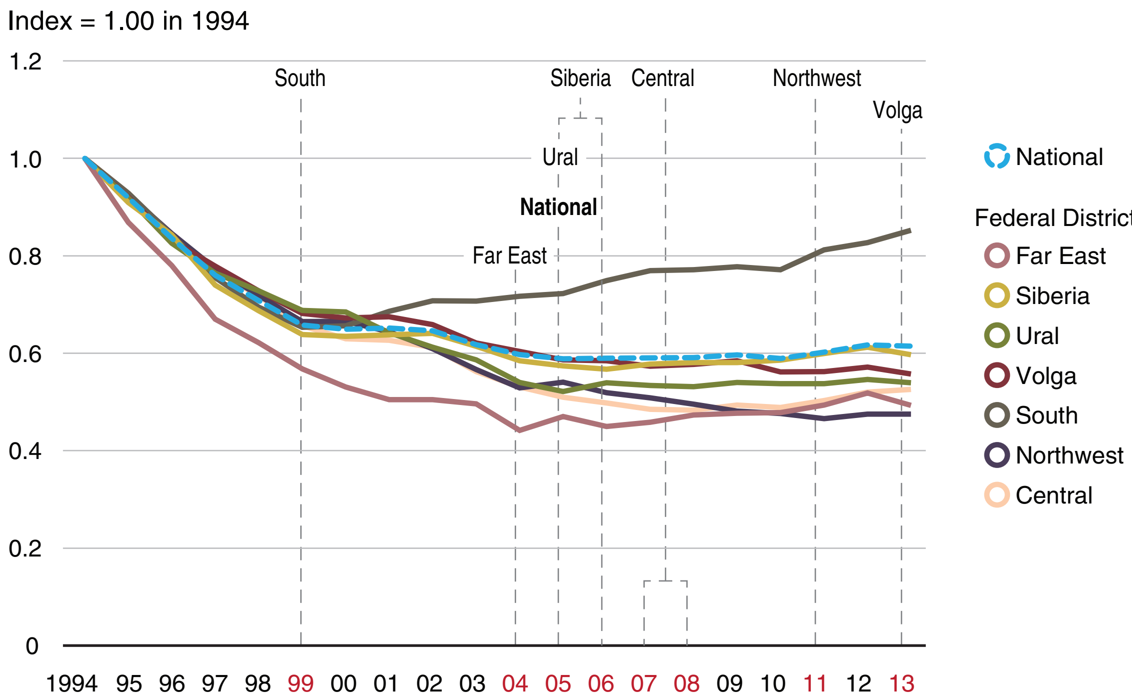
Russia's rebounding agricultural output led by the South district



Note: Data have been smoothed by Hodrick-Prescott filter; lambda = 6.25.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

In the third and final period (2005-13), aggregate input growth became positive at 0.6 percent per year, output growth slowed to 2.3 percent per year, and Russia's agricultural TFP growth dropped to 1.7 percent per year (see fig. 12). The production growth slowdown reflects, in part, weather-driven volatility as revealed by the annual fluctuation in Russian grain production (see fig. 1). But the fact that Russia's aggregate input growth was positive, on average, across Russian districts reflects agricultural recovery from the transition to a market economy. Indeed, in all districts but one, input use has stopped falling, such that districts are at least maintaining, if not increasing, their base level of input use (fig. 14). As such, the modest rate of annual average TFP growth (1.7 percent) estimated for this period across Russia reflects the productive application of conventional inputs to increase agricultural output and provides a reasonable estimate from which one may set future expectations of Russia's agricultural performance. However, as detailed below, that modest TFP growth rate is itself an average of strong and sluggish growth among districts.

Figure 14
Varying inflection points of agricultural input change across Russia



Note: The district identifiers in the plot indicate the inflection point in which input growth turned positive.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

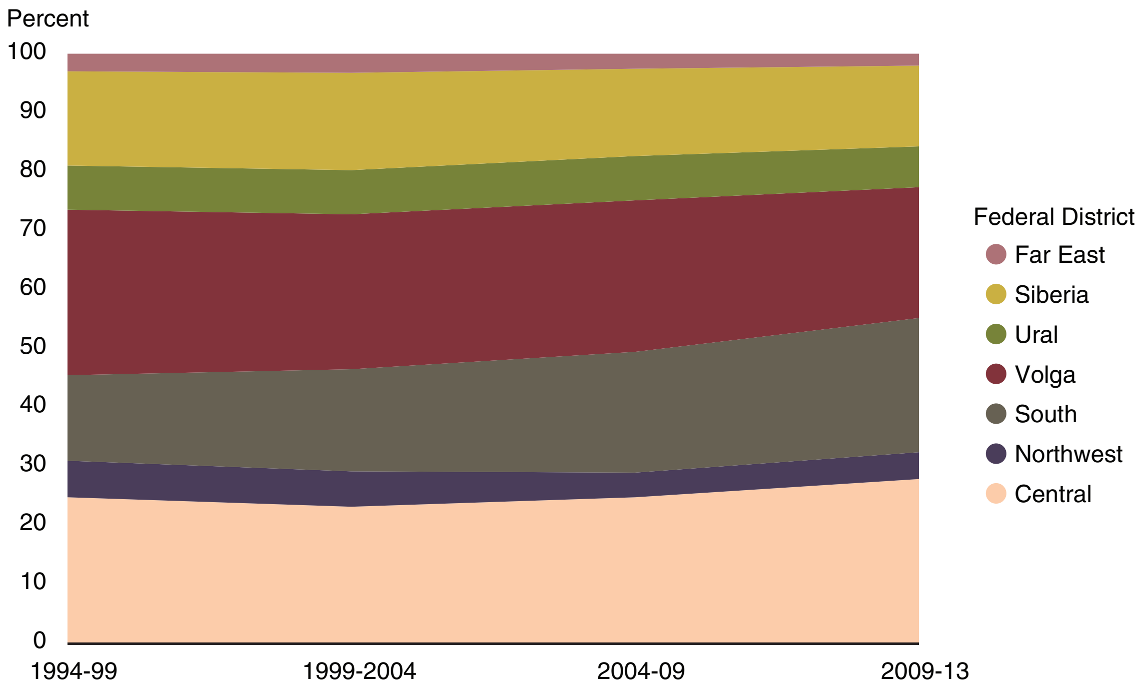
Assessing District Agricultural TFP Growth

The South district reached its input growth nadir in 1999, more quickly than other districts. Input use in the South subsequently grew by 1.8 percent per year until 2013. The district's continued declines in labor, seed, and machinery use were more than compensated by rapid growth in fertilizer and feed and much slower but positive growth in land, fuel, and animal capital. While the South rebounded quickly, the Central district only reached its aggregate input low point in 2007, and as of 2013, the Volga had not achieved positive growth in use of conventional resources. The extreme input shedding by the Central district shows that the district's agricultural sector overexpanded by a large margin during the late Soviet period. Yet, the slight turnaround in input use in 2008 is the basis for some expectations that the district might follow the South's productive efficiency lead. The lack of growth in input use in the Volga, however, should be of concern to Russian policymakers given the district's large share of the Russian agricultural sector's revenues and its key position as Russia's principal meat supplier.

So why did agriculture in the South recover more quickly than in other districts? The South has unique comparative advantages. It has a greater share of high-quality land than other districts (Beinroth et al., 2001). It has a mild climate and long summers that allow for production of winter wheat, corn, and soybeans, crops that can be grown in only a few locations in Russia. The South benefits from Black Sea and Sea of Azov ports through which Russia ships almost all grain exports, and well-developed rail and road systems to transport agricultural output to these ports. Climate, railway infrastructure, and institutions are found to be important determinants of the divergent agricultural productivity growth performances achieved across Russia's regions (Bokusheva et al., 2012; Belyaeva and Hockmann, 2015). With these benefits, it is not surprising that agricultural producers in the South were the first across Russia to rebound. While these factors gave advantages to family farms, they also attracted new operators and agroholdings that have strongly contributed to the district's growth in both the grain and livestock (especially poultry) subsectors (FAO, 2009).

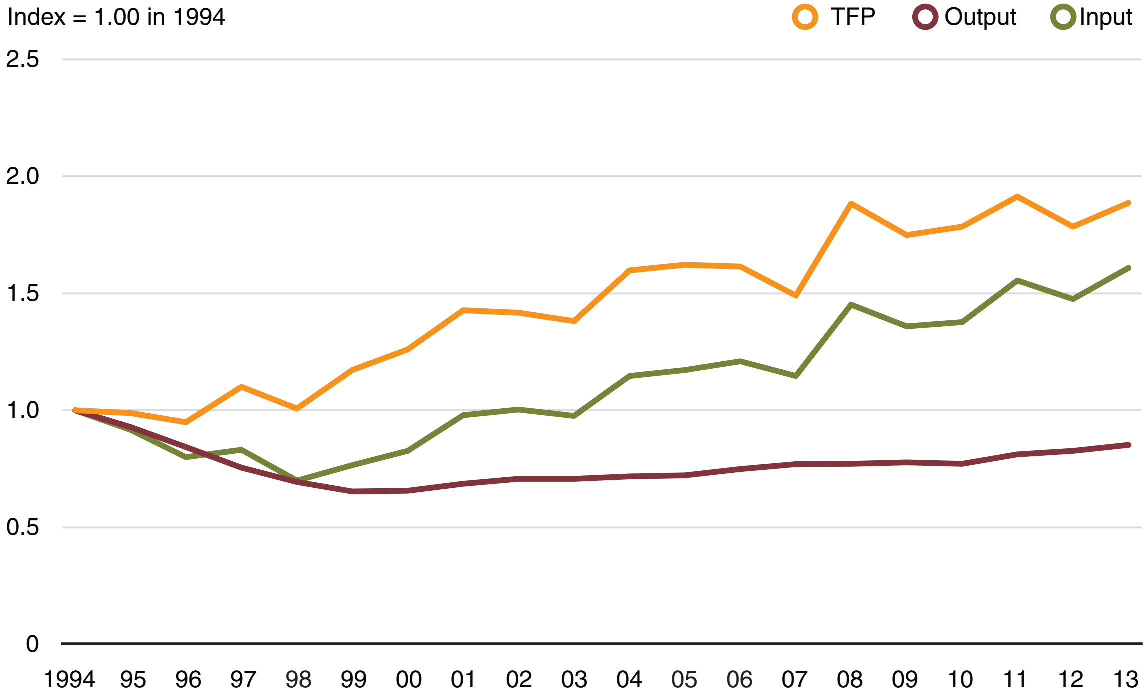
The South and Central districts are Russia's agricultural leaders, accounting for much of the country's growth in TFP (fig. 15). These two districts combined to achieve a 39-percent share of Russia's aggregate TFP growth in 1994-99 and a 51-percent share in 2009-13. While the Central district's share of TFP declined in 1999-2004, the South compensated for that loss such that the combined share of the two districts increased. Indeed, the South increased its share of national TFP growth from 16.5 percent in 1994 to 21.5 percent in 2013, or 2.8 percent each year.

Figure 15
Russian South district's rising share of national TFP growth



TFP = Total factor productivity.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

Figure 16
Russian South district's output, input, and TFP growth



TFP = Total factor productivity.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

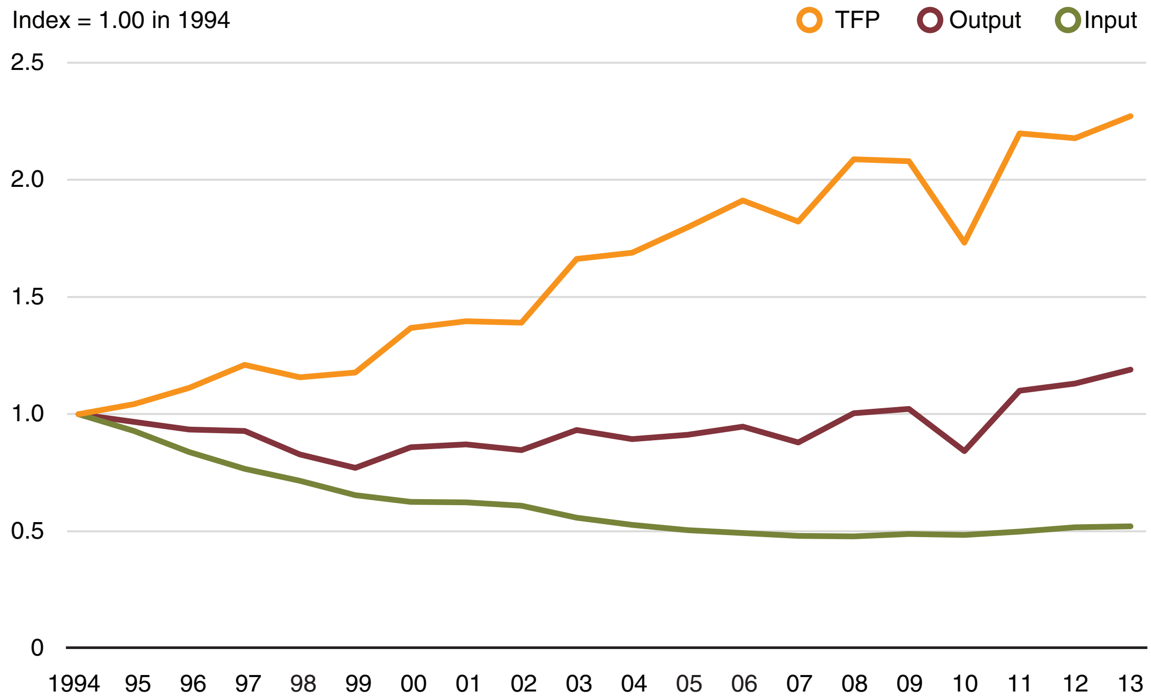
Similar to that in other districts, TFP growth in the South fell from 1994 to 1998. But from 1998 to 2013, TFP in the South grew by 3.6 percent per year (fig. 16). The role of TFP in strengthening agriculture in the South is demonstrated by the fact that 69 percent of the district's output growth in 1998-2013 stemmed from advances in TFP and 31 percent stemmed from higher input use. Thus, the strong TFP growth in the South since 1998, which raised aggregate national output growth in agriculture, was a result of improved technologies and efficiencies rather than greater input use.

Russia's Central district was the only other district to increase its share of national TFP during the study period, from 26 percent in 1994 to 30 percent in 2013 (see fig. 15). Over 1994-2007, the Central district's agricultural TFP growth rate of 5.1 percent per year was almost entirely due to declining input use; agricultural output during this period contracted 0.3 percent each year (fig. 17). However, after 2007, annual average output growth spiked to 4.3 percent, input growth climbed to 1.5 percent, and TFP grew by 2.9 percent each year. Thus, the Central district's agricultural output turnaround was due to 35 percent greater input use but 65 percent greater productivity. These estimates impart cautious optimism regarding the district's agricultural outlook despite the slower TFP growth achieved.

Given the role of TFP in boosting output growth in the South and Central districts, one may question whether Russia's science and technology policies had an impact as well. Russia's Academy of Agricultural Sciences operated 51 research centers and 196 research institutes in 2011 and employs a structure that allows for commodity research over a national scope, with regional institutes focusing on local adaptation (Morgounov et al., 2011). Yet, Russia's agricultural research system has been described as disconnected from the majority of farmers (Morgounov and Zuidema, 2001; Mudahar et al., 1998). Fischer et al. (2016) highlight inadequate smallholder access to technological and managerial innovations and advisory services—factors they attribute to lifting grain yields for large

Figure 17

Russian Central district's output, input, and TFP growth



TFP = Total factor productivity.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

agricultural enterprises such as agroholdings—as a weakness of Russia's agricultural model (Fischer et al., 2016).

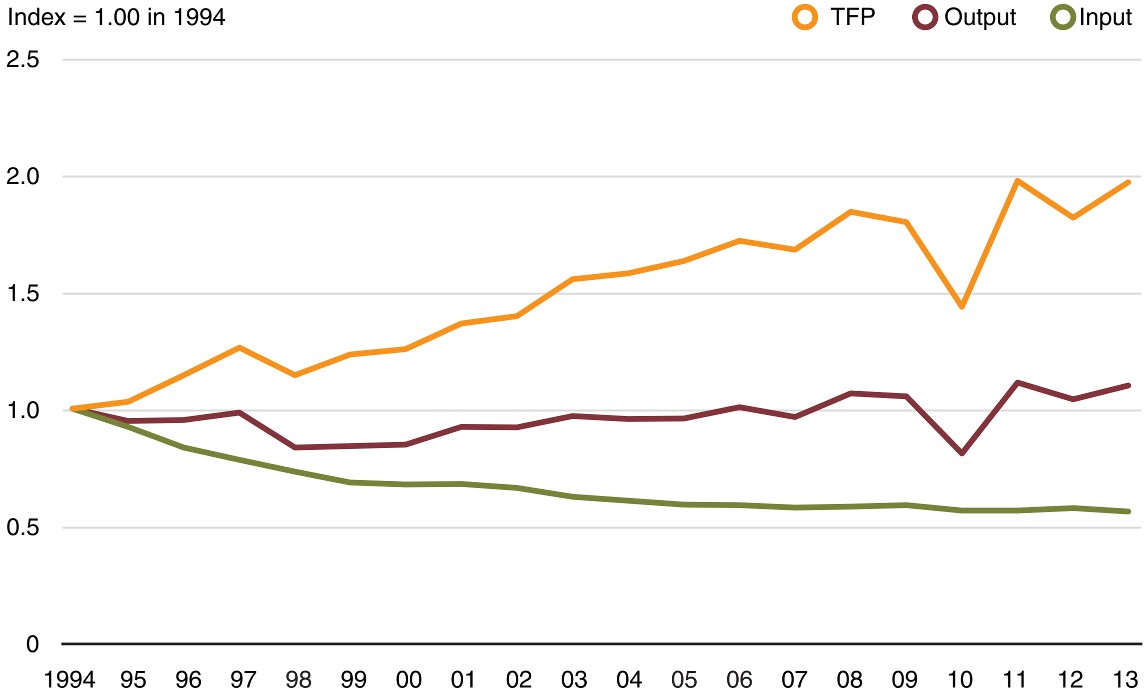
Evidence from the literature of an agricultural research effect on productivity is sparse, and what is available relates to wheat yields. Russian wheat yields are low relative to international standards. Most of Russia's wheat varieties are crosses of domestic varieties, although there is some collaboration with international research.[17] Moreover, wide yield gaps are prevalent between actual farm and potential yields. For example, Russia's spring wheat yield gap ranges from 100 to 175 percent depending on location and period evaluated (Fischer et al., 2016; Mudahar et al., 1998). Factors that may dampen potential yields include biotic stresses (e.g., wheat rust), choice of varietal technology, and low levels of nonland inputs, including irrigation (Shaminin et al., 2016; Fischer et al., 2016; Morgounov et al., 2013).

One may also question whether the South's 1994-2013 TFP growth rate, which was slower than that measured for the Central district, implies that the South underperformed. On the contrary, the South outperformed the Central district because it managed to raise output primarily through productivity improvements. The Central district, on the other hand, achieved somewhat faster TFP growth over the long term than did the South due to slower rates of input growth or no input increase at all (see appendix table 2).

The other agriculturally important district in Russia is the Volga, which has neither stopped its input use from falling nor achieved robust output growth (fig. 18). From 1994 to 2013, output growth in

[17]See: http://wheatatlas.org/country/varieties/RUS/0.

Figure 18
Russian Volga district's output, input, and TFP growth



TFP = Total factor productivity.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

the district averaged only 0.7 percent each year while input use dropped by 2.7 percent each year. As a result, the district's TFP growth rate over the period (3.4 percent each year) is a misleading indicator of agricultural performance. Agricultural production in the Volga did rebound in 1998 and rose by 1.5 percent each year through 2013. Yet, the lack of productive input applications to spur growth as achieved in the South and Central districts is a concern for a district that is ranked second in national meat production and accounts for a substantial share of national agricultural revenue.

Russia's remaining districts (Northwest, Ural, Siberia, and Far East) are of lesser agricultural importance. We briefly note that it has been difficult for these districts to reach 1994 production levels in the years since. By 2013, the Northwest and Far East districts achieved output just below their 1994 levels, while the Ural and Siberian districts achieved output just above that of 1994. Once input growth rebounded in each district, the Far East, Siberia, and Ural experienced stagnant (less than 1 percent per year) or negative TFP growth.

Conclusions and Implications

Russia's large loss of agricultural resources and accompanying fall in output in the 1990s was a necessary though painful correction of the overexpanded and costly agricultural sector of the planned Soviet period. During the mid-1990s, aggregate input use fell by a greater percentage than did output. From the late 1990s to the mid-2000s, however, output increased while input use continued to contract, generating high rates of TFP growth. From the mid-2000s to 2013, output continued to grow while input use (at the aggregate national level) finally bottomed out and started to rise slightly. Although the turnaround in input use reduced TFP growth, increased input use has been a positive development for Russian agriculture, as the large-scale shedding of resources finally abated.

Leading Russia's agricultural revival has been the South district, where producers appear to have exploited climatic, infrastructural, and institutional comparative advantages over other districts. Modern agricultural practices (e.g., hybrid corn combined with specially tailored fertilizer application) and new processes (e.g., vertically integrated poultry operations) have also likely contributed to boosting output. Despite the South's early rebound, the rest of the country has lagged, which explains why aggregate agricultural output grew while input use fell between 1998 and 2005. While the South's share of national production was sufficiently large to raise national output after 1998, its input growth rebound in 1999 was insufficient to raise national input growth. Aggregate input use did not turn positive until three other districts—the Far East, Ural, and Siberia—also reached their input decline nadirs in 2005.

The South's robust TFP growth since 1998 and the Central's TFP growth since 2007 are an optimistic sign for Russia's policymakers and world trade. The South has become the country's dominant grain producer. In light of the Central district's position as Russia's primary meat producer, its recent strong TFP growth may support a long-term growth outlook led by new technologies and efficiencies rather than by additional resources and may indicate an important shift in what has long been an inefficient subsector. Yet, the robust agricultural TFP growth in the South and Central districts has been muted in the national sample by lagging growth elsewhere, especially the Volga.

Russian agricultural TFP growth has implications for world agricultural trade. Expected continued growth in Russian grain production (driven by both rising input use and productivity) will increase the country's exports, putting more competitive market pressure on other major grain exporters, such as the EU, and partly on the United States. In 2016, Russia's record wheat harvest of 73 mmt generated record exports of 29 mmt (USDA, 2016), making the country the world's top wheat exporter for the first time since it gained independence in 1991. Continued growth in Russian meat output will further reduce the country's livestock product imports, affecting large meat exporters to the country, such as the EU and Brazil.

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Appendix: A Review of Technical Details

The sources used for the agricultural output and input data are identified in appendix table 1. For the purposes of data consistency, Komi-Permyak District is merged with Perm Territory, Ust-Orda Buryat District is merged with Irkutsk State, and Agin-Buryat District is merged with Chita State to form Zabaikal Territory. Komi-Permyak and Perm Territory merged in 2004, while the others merged in 2008.

Output Data

The Russian agricultural output data include grains, sunflower seed, sugarbeets, potatoes, vegetables, flax, meat, milk, and eggs. Output is defined as annual production and does not include stocks or imports. Data for these nine commodities are available annually to the authors for the years 1994-96 and 1999-2013. Missing national data (1997-98) were primarily interpolated using Food and Agriculture Organization of the United Nations growth rates (FAO, 2015); missing State data were often interpolated using national growth rates. All output data are recorded in metric tons. All prices and values are converted to 2000 constant rubles using the World Bank's gross domestic product (GDP) deflator specific to Russia (WDI, 2015). The nine crop and livestock outputs are aggregated into a single chain-weighted Tornqvist-Theil quantity index.

Input Data

The input data consist of labor, land, material, capital, and fuel inputs specific to the agricultural sector. Due to a lack of data availability, each input quantity variable is specified as a stock measure. We assume a fraction of the stock is provided to farms in the form of service flows which change at the same rate as the stocks. If, on average across inputs, service flow benefits grow faster (slower) than the stocks then the TFP estimates would be biased upward (downward).

Labor

The number of agricultural laborers is available annually from 1994 to 2004. However, between 1994 and 1998, the regional data exclude labor on family farms. The national-level data, however, include family farm data. We therefore correct the regional data by applying the national growth rate to each region during these years.

From 2004 to 2013, the number of agricultural laborers is combined with forestry labor data. To obtain agricultural labor estimates from 2004 to 2013, we first estimate agricultural labor's share of total agricultural and forestry labor between 1994 and 2004. We then estimate trend growth in agriculture's labor share from 1998 to 2013. The trend growth rates, at the State, district, and national levels, are applied to extend the agricultural labor shares from 2004 to 2013. Multiplying the agricultural-labor share data with the total number of agricultural and forestry laborers, and combining these data with the extant 1994-2004 agricultural labor data, provides annual farm labor estimates for the entire 1994-2013 sample period.

Agricultural wages are available annually from 1994 to 2004. However, from 2000 to 2013 wage data are available only for agriculture and forestry combined. The ratio of agricultural to agricultural-and-forestry wages was 0.92 during the overlapping years of 2000-2004; that is, agricultural wages were on average 92 percent of the combined agricultural and forestry wages between 2000 and 2004. We employ this rate to estimate agricultural wages over the 2005-13 period from the agricultural and forestry wage data. Combining these agricultural wage estimates with the extant 1994-2004 agricultural wage data provides the annual wage series at the national level.

Materials

Material inputs consist of synthetic crop fertilizers and seeds. Quantities of fertilizer supplied to the agricultural sector are available as an aggregate from 1994 to 1996, and from 1999 to 2013. Data for the missing years of 1997 and 1998 were obtained by assuming FAO growth rates (FAO, 2015). No data on individual nitrogen, phosphate, and potash quantities are available. Aggregate fertilizer prices are only available from 1994 to 2001. However, the prices of nitrogen, phosphate, and potash fertilizers are available annually. We estimate 2002-13 aggregate fertilizer prices by summing nitrogen, phosphate, and potash fertilizer prices, weighted by their respective FAO quantity shares of fertilizer consumption (FAO, 2015).

Seed inputs reflect FAO data specific to grain, potato, and sunflower seeds (FAO, 2015). These annual, national-level data are allocated to States using national shares of sown area. An aggregate seed input price is estimated by weighting cereal, potato, and sunflower seed output prices—marked up by 50 percent to account for cleaning, sorting, and storage costs—by their seed input quantity shares.

Animal Capital and Feed

Data for the stocks of cattle, pigs, and sheep and goats are available from 1994 to 1996 and from 1999 to 2013. Missing 1997 and 1998 data assume FAO growth rates (FAO, 2015). Poultry stocks, however, are only available from 1994 to 1996. FAO growth rates are employed to extend the data from 1996 to 2013. The stocks of cattle, pigs, poultry, and sheep and goats are aggregated into cattle-equivalent animal capital stocks using as aggregation weights each animal's 1994-2013 average FAO import price per head, normalized by the cattle import price. The animal capital service price is the FAO import price specific to cattle and depreciated by 10 percent.

Feed inputs are available in tsentners per head and reflect the amount of feed supplied to a representative animal for a given year on an agricultural enterprise.[18] These feed data are converted to metric tons and multiplied by an estimate of the cattle-equivalent animal capital stocks on agricultural enterprises.

Machinery Capital and Fuel

Machinery capital is measured as the onfarm stocks of tractors, grain harvesters, and sugarbeet harvesters, aggregated using tractor-normalized prices. Sugarbeet harvester prices are unavailable, so the grain harvester price is assumed. We convert grain harvester and tractor sale prices to service prices by depreciating them by 10 percent. Fuel inputs consist of gasoline and diesel. Data for these fuels are available in years 1994 and 1999-2013 and are linearly interpolated for missing years.

[18] 1 tsentner = 100 kilograms, such that 10 tsentners = 1 metric ton.

Total Factor Productivity Measurement

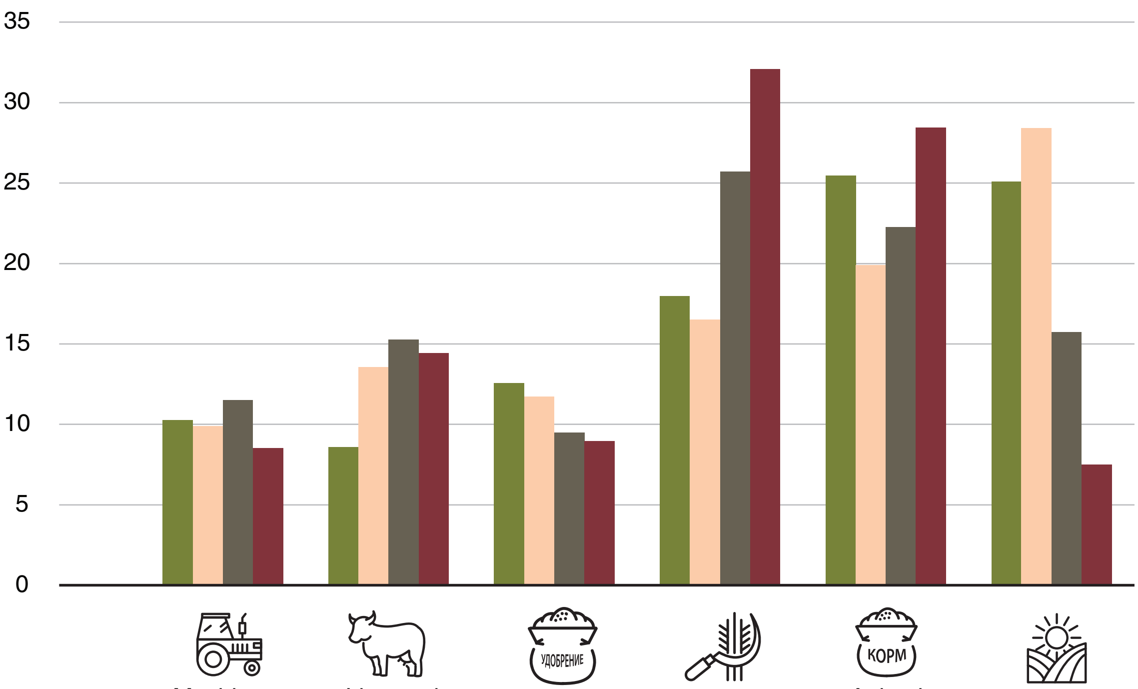
We measure Russia's agricultural TFP growth using a chain-weighted Tornqvist-Theil quantity index. The chain-weighted Tornqvist-Theil TFP growth index may be expressed as

(Eq 1)
$$\ln\left(\frac{TFP_{i,t}}{TFP_{i,t-1}}\right)=\left[\sum_{j}\frac{\left(R_{ij,t}+R_{ij,t-1}\right)}{2}\ln\left(\frac{Y_{ij,t}}{Y_{ij,t-1}}\right)\right]-\left[\sum_{l}\frac{\left(C_{il,t}+C_{il,t-1}\right)}{2}\ln\left(\frac{X_{il,t}}{X_{il,t-1}}\right)\right]$$

where i indicates the region, district, and national production panels, $i = 1, 2,\ldots, 23$; j indicates the commodities included, $j = 1, 2,\ldots 9$; l indicates the factors of production, $l = 1, 2, \ldots, 6$; t indicates time, $t = 1994, 1981,\ldots, 2013$; R is the revenue share; Y is output; C is the cost share, and X is input. Equation (1) expresses aggregate TFP growth of observation i, between time periods t and $t\text{-}1$, as the difference between aggregate output growth and aggregate input growth. Aggregate output growth is defined as the sum of all commodity output growth rates, and each growth rate weighted by its respective average revenue share in the reference time periods. Input growth is defined as the sum of all factor input growth rates, and each growth rate weighted by its respective average cost share in the reference time periods (app. fig. 1).

Appendix figure 1

Labor's rising share of national input expenditures in Russia, averaged by 5-year period



	Machinery capital	Livestock capital	Materials	Labor	Animal feed	Land
1994-1999	10	9	13	18	25	25
1999-2004	10	14	12	17	20	28
2004-2009	12	15	9	26	22	16
2009-2013	9	14	9	32	28	8

Note: All estimates are specified as percents.
Source: USDA, Economic Research Service using Russian Federal State Statistics Service and Ministry of Agriculture data.

Appendix table 1
Agricultural production data sources

Series	Unit of measure	Level of aggregation	Source
Crop and animal products	Metric tons	Region (Oblast)	Ministry of Agriculture of the Russian Federation, Department of Economics, *Agro-Industrial Complex of Russia* (1995 - 2013).
Agricultural labor	Counts	Region (Oblast)	Russian Federal Service of State Statistics, Rosstat electronic publication catalogue, *Labor and Employment*. Available at: http://www.gks.ru/bgd/regl/B03_36/Main.htm. Accessed on July 2012.
Agricultural wages	Rubles	Region (Oblast)	Russian Federal Service of State Statistics, Rosstat electronic publication catalogue, *Labor in Russia*. Available at: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog/doc_1139916801766. Accessed on July, 2012.
Land	Hectares	Region (Oblast)	Ministry of Agriculture of the Russian Federation, Department of Economics, *Agro-Industrial Complex of Russia* (1995 - 2013).
Fertilizer inputs	Metric tons	Region (Oblast)	Ministry of Agriculture of the Russian Federation, Department of Economics, *Agro-Industrial Complex of Russia* (1995 - 2013).
Fertilizer prices	Rubles	National	Russian Federal Service of State Statistics, Rosstat electronic publication catalogue, *Prices in Russia*. Available at http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog/doc_1138717314156.
Seed inputs	Metric tons	National	Food and Agricultural Organization (FAO), FAOSTAT 2015. Available at: http://faostat3.fao.org/home/E. Accessed on October 8, 2015.
Animal stocks	Counts	Region (Oblast)	Ministry of Agriculture of the Russian Federation, Department of Economics, *Agro-Industrial Complex of Russia* (1995 - 2013).
Animal stock prices	Rubles	national	Food and Agricultural Organization (FAO), FAO STAT 2015. Available at: http://faostat3.fao.org/home/E. Accessed on September 23, 2015.
Feed inputs	Metric tons per head	Region (Oblast)	Ministry of Agriculture of the Russian Federation, Department of Economics, *Agro-Industrial Complex of Russia* (1995 - 2013).
Feed prices	Rubles	National	Russian Federal Service of State Statistics, Rosstat electronic publication catalogue, *Prices in Russia*. Available at http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog/doc_1138717314156.
Machinery stocks	Counts	Region (Oblast)	Ministry of Agriculture of the Russian Federation, Department of Economics, *Agro-Industrial Complex of Russia* (1995 - 2013).
Machinery prices	Rubles	National	Russian Federal Service of State Statistics, Rosstat electronic publication catalogue, *Prices in Russia*. Available at http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog/doc_1138717314156.
Fuel inputs	Metric tons	Region (Oblast)	Ministry of Agriculture of the Russian Federation, Department of Economics, *Agro-Industrial Complex of Russia* (1995 - 2013).

Appendix table 2

National and district chain-linked Tornqvist-Thiel output, input, and TFP growth indexes

	National			South			Central		
Year	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP
1994	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1995	0.96	0.92	1.05	0.92	0.93	0.99	0.97	0.93	1.04
1996	0.92	0.84	1.10	0.80	0.84	0.95	0.93	0.84	1.11
1997	0.93	0.76	1.22	0.83	0.76	1.10	0.93	0.77	1.21
1998	0.81	0.71	1.14	0.70	0.69	1.01	0.83	0.72	1.16
1999	0.81	0.66	1.24	0.77	0.65	1.17	0.77	0.66	1.18
2000	0.86	0.65	1.32	0.83	0.66	1.26	0.86	0.63	1.37
2001	0.93	0.65	1.42	0.98	0.69	1.43	0.87	0.63	1.39
2002	0.93	0.65	1.44	1.00	0.71	1.42	0.85	0.61	1.39
2003	0.96	0.62	1.55	0.98	0.71	1.38	0.93	0.56	1.66
2004	0.97	0.60	1.63	1.15	0.72	1.60	0.89	0.53	1.68
2005	0.98	0.59	1.67	1.17	0.72	1.62	0.91	0.51	1.79
2006	1.02	0.59	1.73	1.21	0.75	1.61	0.95	0.50	1.90
2007	0.96	0.59	1.63	1.15	0.77	1.49	0.88	0.48	1.82
2008	1.09	0.59	1.84	1.45	0.77	1.88	1.00	0.48	2.08
2009	1.09	0.60	1.83	1.36	0.78	1.75	1.02	0.49	2.07
2010	0.97	0.59	1.64	1.38	0.77	1.79	0.84	0.49	1.73
2011	1.18	0.60	1.95	1.55	0.81	1.91	1.10	0.50	2.19
2012	1.12	0.62	1.82	1.48	0.83	1.79	1.13	0.52	2.17
2013	1.20	0.61	1.96	1.61	0.85	1.89	1.19	0.53	2.26
					Percent				
1994-2013 Annual average growth	1.33	-2.15	3.48	3.81	-0.07	3.88	0.94	-3.47	4.41

Note: Growth rates are estimated using Microsoft® Excel's ln(logest()) function, which estimates logarithmic trend growth for a data series and employs an econometric error. USDA, Economic Research Service estimates.

Appendix table 2 (continued)

National and district chain-linked Tornqvist-Thiel output, input, and TFP growth indexes

	Volga			Northwest			Ural		
Year	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP
1994	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1995	0.95	0.92	1.03	1.06	0.92	1.14	1.00	0.92	1.09
1996	0.95	0.83	1.14	0.98	0.85	1.16	0.98	0.83	1.19
1997	0.98	0.78	1.26	0.96	0.77	1.24	0.99	0.76	1.30
1998	0.83	0.73	1.14	0.88	0.72	1.23	0.86	0.73	1.18
1999	0.84	0.68	1.23	0.93	0.67	1.40	0.94	0.69	1.36
2000	0.84	0.67	1.26	0.94	0.67	1.41	0.89	0.68	1.30
2001	0.92	0.68	1.36	0.95	0.64	1.48	0.94	0.64	1.47
2002	0.92	0.66	1.40	0.95	0.61	1.56	0.97	0.61	1.59
2003	0.97	0.62	1.56	0.92	0.57	1.63	1.00	0.59	1.71
2004	0.95	0.60	1.58	0.89	0.53	1.69	0.95	0.54	1.76
2005	0.96	0.59	1.63	0.89	0.54	1.65	1.05	0.52	2.01
2006	1.01	0.58	1.72	0.89	0.52	1.72	1.12	0.54	2.07
2007	0.96	0.57	1.68	0.75	0.51	1.47	0.99	0.53	1.85
2008	1.07	0.58	1.85	0.78	0.50	1.58	1.02	0.53	1.92
2009	1.05	0.58	1.80	0.81	0.48	1.68	1.08	0.54	2.00
2010	0.81	0.56	1.44	0.82	0.48	1.71	0.97	0.54	1.80
2011	1.11	0.56	1.98	0.88	0.47	1.88	1.21	0.54	2.26
2012	1.04	0.57	1.82	0.90	0.48	1.89	1.03	0.55	1.89
2013	1.10	0.56	1.97	0.93	0.48	1.95	1.11	0.54	2.06
					Percent				
1994-2013 Annual average growth	0.71	-2.67	3.38	-0.96	-3.85	2.88	0.77	-3.04	3.81

Note: Growth rates are estimated using Microsoft® Excel's ln(logest()) function, which estimates logarithmic trend growth for a data series and employs an econometric error. USDA, Economic Research Service estimates.

Appendix table 2 (continued)

National and district chain-linked Tornqvist-Thiel output, input, and TFP growth indexes

	Siberia			Far East		
Year	Output	Input	TFP	Output	Input	TFP
1994	1.00	1.00	1.00	1.00	1.00	1.00
1995	0.98	0.91	1.07	1.04	0.87	1.20
1996	0.90	0.84	1.07	0.98	0.78	1.26
1997	0.91	0.74	1.23	0.97	0.67	1.45
1998	0.79	0.69	1.14	0.88	0.62	1.41
1999	0.78	0.64	1.23	0.91	0.57	1.61
2000	0.88	0.63	1.39	0.88	0.53	1.67
2001	0.93	0.64	1.45	0.99	0.50	1.96
2002	0.97	0.64	1.52	1.01	0.50	1.99
2003	0.95	0.61	1.54	1.03	0.50	2.07
2004	0.96	0.58	1.65	1.00	0.44	2.27
2005	0.94	0.57	1.63	0.99	0.47	2.10
2006	0.96	0.57	1.69	1.03	0.45	2.30
2007	0.96	0.58	1.65	0.86	0.46	1.89
2008	0.98	0.58	1.69	0.92	0.47	1.94
2009	1.08	0.58	1.86	0.94	0.48	1.97
2010	1.02	0.59	1.75	0.94	0.48	1.96
2011	1.08	0.60	1.81	0.99	0.49	2.01
2012	0.98	0.61	1.59	1.01	0.52	1.95
2013	1.12	0.60	1.88	0.94	0.49	1.91
			Percent			
1994-2013 Annual average growth	0.95	-2.18	3.13	-0.09	-3.00	2.92

Note: Growth rates are estimated using Microsoft® Excel's ln(logest()) function, which estimates logarithmic trend growth for a data series and employs an econometric error. USDA, Economic Research Service estimates.