Modernization in Progress: Part-Year Operation, Capital Accumulation, and Labor Force Composition in Late Imperial Russia[*]

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Abstract

Our research investigates the process of industrialization by examining why some Imperial Russian firms operated only part of the year. We relate a factory's annual number of working days to labor composition, extent of mechanization, performance, and regional location to understand whether Late Imperial Russia experienced industrialization processes similar to those in Western countries, where such processes are better understood. We use a newly compiled factory database collected from an 1897 factory census to present detailed descriptions of all manufacturing firms operating in 1894 Imperial Russia. We find that factories using more capital were more likely to operate all year, given the high costs of idle machinery. Furthermore, full-year factories with more machines were also more concentrated in cities, similar to what Atack et al. (2001) found in the 19th century United States, and employed more women and children. Factories that operated a greater number of working days per year were also more productive and more likely to survive, evidence that seasonal operation was a transitional phase in Russia's industrial development. Finally, we present some suggestive evidence that factories were more likely to operate seasonally in regions that depended more heavily on grain agriculture.

JEL Codes: N63, O13, O14

1. Introduction

Economic history provides an opportunity to examine the experience of an industrializing or modernizing society over a long horizon as significant transformations unfold. Economists still know relatively little about the repertoire of peculiar adaptations factories might have implemented to overcome missing or thin input markets and other obstacles encountered while industrialization was ongoing, especially in late-industrializing contexts. This paper examines part-year or seasonal factory operation, a once-widespread industrial practice seldom discussed by more recent literature in economics or economic history, particularly when describing contexts outside the United States or Great Britain. Part-year operation has likely been so neglected in the literature, because data requirements are substantial. Sources listing factory working time, even that the aggregate level, are exceedingly rare. Moreover, unpacking the elemental relationships among a factory's working time, location, technology, and productivity requires detailed firm-level or enterprise-level data.

This paper investigates the relationships among seasonal operation, labor force composition, and production technology in a rapidly-modernizing late-industrializing country, Imperial Russia. At the end of the nineteenth century, the Russian Empire remained intensely agrarian, but its industrial sector was growing relatively rapidly.[1] Because of the preeminence of seasonal agriculture in the economy and difficulty attracting industrial labor, many factories located outside of cities in the country and adjusted worktime to accommodate labor-intensive agricultural seasons. This paper investigates seasonal operation and argues that factories that operated seasonally tended to be located in rural areas, to use less machine power, to be less productive, and to be more likely to perish before 1900, which suggests that seasonal operation would gradually disappear from Russian industry over the long run.

[1] Russian real GDP per capita in 2011 USD was $2069 in 1895, compared to $3675 in France, $5068 in the UK, or $4044 in Germany (Maddison's estimates, cgdppc). The Russia's average annual growth rate of real GDP from 1885 to 1900 was 2.2 percent (calculated from Maddison's estimates, rgdpnapc). Crisp (1976) estimated average annual rates of industrial growth in the Russian Empire of 6.10 percent from 1885-1890 and 8.03 percent from 1890 to 1899 (p. 111). Kahan (p. 21) shows that Russian steel output increased from 183 thousand tons in 1885 to 1.39 million tons in 1895. Similarly, pig iron output increased from 527 thousand tons to 1.45 million tons in 1895.

This investigation relies on a uniquely detailed factory-level dataset, collected by Gregg (2019) covering over 13,500 factories in the year 1894 that lists the number of working days per year that each factory operated and wealth of other critical variables. The dataset permits a series of tests about the relationships among part-year operation, labor force composition, and capital accumulation, because the data provide rich detail on each factory, including the machines each factory uses, the factory's total annual revenue, the precise activities undertaken by the enterprise, and the factory's labor force composition. Matching to an additional factory-level dataset from 1900 permits us to test whether seasonal factories were more likely to exit. We also examine the relationship between part-year industrial operation and agricultural production using regional data on the Russian Empire collected by Kessler and Markevich (2014).

If seasonal operation is costly, part-year operation may represent a transitional stage of industrial development. Factories that operated during only one part of the year left any capital investments idle during the part of the year they shut down. A theory of Smithian growth through the division of labor would predict that part-year operating factories would disappear in the long run. This simple framework motivates a cluster of hypotheses about part-year operation in Russian factories. We expect to find that factories operating more than the median days of the year (240) should have more fixed capital as measured by machine power than those operating more seasonally, to be more productive, and to be more likely to survive past 1894. Additionally, part-year operating factories may be more likely to be located in rural areas, where factories would shut down to accommodate agricultural labor demands. If part-year operation constrained the overall size of enterprises, factories operating part-year will be smaller as measured by total workers. We examine these relationships with a series of standard tests.

Our paper's results contribute to literatures in economics and economic history by broadening our empirical historical understanding of seasonal factory operation to a late industrializing region, by highlighting an important dimension to discussions of productivity in developing economies, and by applying new data to a set of canonical questions in Russian history. Data limitations for studying operating time were overcome for the U.S. case thanks to the highly detailed U.S. Census of

Manufactures, which enabled a particularly influential line of inquiry describing U.S. factory development as it unfolded. The Russian data permits a comparison to this case, and our paper finds that many of the relationships uncovered in this literature, for example the relationships among size, capital intensity, and part-year operation, also appear to characterize factories in the Russian Empire, a very different setting, suggesting the existence of some important economic laws of motion for factory operating time.

Our paper closely relates to ongoing debates that seek to understand sources of productivity differences across countries.[2] Hsieh and Klenow's (2009) result that misallocation of inputs between more and less productive firms explains a large percentage of TFP differences between the US and India or China has encouraged an inquiry into the sources productivity differences across firms within the same industry. Micro-level studies of how firms in developing contexts actually operate, for example Bloom and Van Reenan (2007) and Bloom et. al. (2013) shed enormous light on potential sources of these differences. Our paper's examination of seasonality and its relationship to factory technology and productivity adds an important dimension to this inquiry.

Finally, our paper represents a significant new contribution to one of the oldest literatures in Russian economic history, the Marxist debate about Russia's stage of capitalist development on the eve of the October Revolution. Soviet and pre-Soviet socialist economists wrote extensively about seasonal operation in Russian factories and worker migration between the countryside and industrial towns in order to establish the degree to which Russia had reached a capitalist stage of production. We boldly suggest that our paper makes progress on this older literature, since we are able to study all of Russian industrial production at the factory level at a particular snapshot in time.

The paper proceeds as follows. First, we outline a literature in economics that relates seasonal operation, mechanization, and the composition of the factory's labor force in other contexts. We then

[2] Additionally, for development economists, interactions between industry and agriculture have long represented a central topic of inquiry, from classics like Harris and Todaro's (1970) two-sector model to Munshi and Rosenzweig's (2016) structural analysis of the urban-rural wage gap.

relate this study to an older Russian literature on seasonal factory operation. Next, we relate these literatures to what we know about Russian industrial development to form a set of hypotheses. After describing the 1894 factory data in detail, we test these hypotheses. We conclude with a discussion of the implications of our findings and an agenda for future research.

2. Empirical Studies of Part-Year Operation, Production Technology, and Labor Markets in the United States and Great Britain

A small but important literature has examined part-year operation among industrial leaders such as the United States and Great Britain. This literature stresses the relationship between part-year operation and seasonal agriculture and the consequences of part-year operation for factory production and performance, particularly when part-year operation relates to transitions from home production to artisanal shop manufacturing and to industrial factory production.

Two key issues frame the economic history literature that describes industrial transitions: first, whether such changes in factory organization were actually associated with improvements in productivity or firm survival (e.g., Sokoloff 1984) and, second, why such changes happened when and where they did. Sokoloff and Dollar (1997) show that, due to a higher land-to-labor ratio, agriculture in the United States was more varied and less seasonal. In the United States, workers could gather in the same place to manufacture goods without consistent seasonal pressure from the agricultural labor market. Thus, U.S. industrial producers adopted the manufactory model. In the UK, however, a lower land-to-labor ratio resulted in a higher overall reliance on grains, which are highly seasonal, leading industrial entrepreneurs to adopt the cottage industry model, in which an entrepreneur provided inputs and marketed the output of workers who manufactured goods at home. The cottage industry model provided the workers the flexibility to accommodate such varying demand for agricultural labor. Similarly, within the United States, Sokoloff and Tchakerian's (1997) study of manufacturing in the rural South and Midwest in the 1860 U.S. Census of Manufactures shows that manufacturers were less productive and more seasonal in places practicing wheat agriculture. Agricultural labor markets influenced the development of industry.

Thus, even though U.S. manufacturers were less sensitive to seasonality than British producers, manufacturing firms in the United States were thus still somewhat tied to the labor demands of agriculture. Atack, Bateman and Margo (2002) document that 38-40% of establishments operated for less than twelve months a year, suggesting a substantial presence of seasonal operations that accommodated agricultural needs. They also find that larger firms with more labor and capital, worked, on average, longer than smaller firms, and suggest that large, capital-intensive firms had higher termination costs as well as an ability to accommodate for business cycles without suspending operations. They also find that possessing larger steam power was negatively related to working longer, but positively with working hours, which they explain by the necessity for periodic maintenance of steam-powered machines, which was better achieved during down-times, but economic efficiency was achieved by operating the machinery longer hours per day. Overall, these more factory-like firms were less dependent on agriculture and operated longer on annual basis.

The changing labor composition of manufacturing establishments also influenced the development of industry. In the United States, women and children participated actively in industry; in the 1800s, 40% of industrial laborers were women and children. Goldin and Sokoloff (1984) argue that an important reason the American Northeast industrialized faster than the South was that women and children had relatively lower productivity in agriculture in the Northeast than in the South. Women and children thus had high relative productivity in manufacturing and therefore entered the manufacturing labor force in large quantities, which helped develop the northern industrial sector. This logic might suggest that firms with higher female-to-male ratios would be more likely to resemble industrial, factory-style companies and thus operate for longer periods of time.

3. Seasonality and Industrial Development in the Russian Empire

Through Russia's industrial sector grew impressively in the late nineteenth century, agriculture was still the major sector of the economy. By 1897, agriculture still accounted for more than 50% of the Gross Regional Product of the Russian Empire, while industry accounted for less than 20% (Markevich

2018). The relationship between these two sectors was the subject of major debates at the time and through the Soviet period. Contemporary and Soviet economists worried that labor was often diverted to agriculture during planting and harvest, possibly slowing down the rate of industrial development. Some manufacturing firms even completely shut down when agricultural work was most intensive. Estimates of rates of urban-rural migration (especially return migration) and of the pervasiveness of part-year operation occupied an important place particularly in debates about Russia's level of evolution as a capitalist, industrial economy.

To Russia's socialist economists, the continued prevalence of part-year operation indicated that Russian industrialization remained at an intermediate stage of development. Given the political stakes, it is no surprise that the socialist and Soviet-era literature on the topic is immense. Even Lenin mentioned part-year operation in his classic work composed while he was in prison and exile, *The Development of Capitalism in Russia.* To Lenin, at early stages of capitalism, industrialists had "hardly yet become differentiated" from peasants. Part-year operation was a sign of backwardness. Lenin makes a set of empirical predictions about the relationship between part-year operation and factory production. For example, he remarks that larger establishments usually operate longer, because such factories have larger, more stable work forces that allowed them to more completely specialize as industrial establishments.[3]

Earlier writers similarly related part-year operation to stages of development. In particular, Tugan-Baranovsky claims that recent evidence had refuted the stereotype that a typical Russian factory worker tended to be "a peasant living on the land who makes up deficiencies of his agricultural income by occasional factory work" and hence refutes the claim that "there is no factory proletariat in Russia" (p. 355).[4] As evidence of the development of the Russian proletariat, Tugan-Barnovsky cites Dement'ev's

[3] Lenin, pp. 373-81.
[4] The full quote evocatively conveys the tone of much of this literature. "What is the modern factory worker in Russia – a peasant living on the land who makes up deficiencies of his agricultural income by occasional factory work, or a proletarian bound closely to the factory who lives by selling his labor power? The usual reply is that there is no factory proletariat in Russia. The Russian factory worker is unlike the West European; he always has a roof over his head and his land to which he can return in time of need. Even 'having been cooked in the factory boiler,' the muzhik remains the same muzhik, submissive to the 'power of the land'" (p. 355).

earlier study of Moscow Province factories in 1884-85. Dement'ev collected exhaustively detailed statistics on the factories he surveyed, painstakingly counting Sundays and holidays to explain that most factories by this period worked essentially full-year with well-justified breaks[5] and that "only the more primitive factories, where hand labor still prevailed, allowed their workers to depart in the summer" (Johnson p. 35). Walkin (1954 p. 163) argues that Dement'ev probably exaggerated the degree to which full-year operation prevailed in Russian factories (perhaps due to sample selection bias). Our study provides an opportunity to revisit some of Dement'ev's claims with more comprehensive data.

Russian factory managers viewed full-year operation as an outcome of imposing effective factory discipline. New factory workers in any context must adapt to strict schedules and a need for coordination and attention in the factory.[6] Many of Russia's factory workers at the turn of the twentieth century were illiterate peasants for whom factories provided housing (Rimlinger 1960 p. 70). According to Rimlinger's study, factory managers became frustrated with workers who wanted to return to their home villages for seasonal agricultural work, since such return migration "delayed the workers' full commitment to factory life, promoted labor instability and unreliability, and hampered the development of industrial skills" (Rimlinger 1960 p. 71). Managers' strategies for coping with this particular problem of discipline included locking factory gates and setting strict rules for who could visit factory workers (p. 71). The structure of Russia's agricultural institutions, and how they evolved over time, made this type of factory discipline problem particularly acute in Imperial Russia.

Recent studies have provided new quantitative evidence on the results of changes in Russian agricultural institutions for the overall economy. Markevich and Zhuravskaya (2017), for example, document that industrial output increased as a result of the 1861 Abolition of Serfdom. Removing the labor tying implied by serfdom would in theory permit former serfs to move to positions in cities offering a higher return. Indeed, Markevich (2018) documents that in 1897, the value added per worker in industry

[5] See especially Dement'ev pp. 109-11.
[6] See, for example, Pollard's (1963) classic essay on factory discipline, which describes how workers "who left the background of his domestic workshop or peasant holding for the factory, entered a new culture as well as a new sense of direction" (p. 254). This description of English factory workers suits the Russian case equally well.

was about 1.6 times higher than in agriculture. However, the abolition of serfdom also included two provisions limiting labor mobility: first, former serfs were not given land title and hence could not sell plots to finance relocation, and second, former serfs were subject to a new internal passport system. Chernina et al. (2014) document that the Stolypin Reform of 1906, which gave former serfs property rights (title) to their plots, implied an economically significance increase in migration, particularly to Siberia.

Our paper also considers whether factories that operated longer than median employed more diverse labor forces. Ulianova (2009) argues that, as industry developed, women and children entered the workforce at higher rates. We investigate whether women and children tended to enter the workforce in more formal, factories that operated more days annually or whether they tended to be employed in part-year factories facing labor scarcities.

Our factory-level dataset covering the entire Russian Empire can thus shed light on several central questions in Russian economic history. We peer inside factories to investigate how part-year operation related to urban location, capital intensively, and labor force composition.

4. Data and an Overview of Part-Year Operations in Russia

Uniquely detailed data provided by the 1894 Russian Manufacturing Census (*Russian Factory Production: List of Factories and Plants*, 1897) allows us to study the relationships among part-year operation, firm organization, and production technology in the Russian Empire. The 1894 manufacturing data provides a factory-level snapshot of industrial activity in the Russian Empire at the end of the nineteenth century. The database covers all industrial factories in the Russian Empire during 1894-5, where a factory is defined as a productive entity with at least 15 employees, a steam boiler, a steam engine, or other factory devices.[7]

[7] Original surveys, page 1, some of which are available at the Russian State Historical Archive (RGIA) Fond 20 Opis' 12.

Crucially, the database provides the number of days a factory worked in that year, our indicator of part-year operations. The database also lists a factory's name; street address; complete list of production activities and products; number of workers by age and gender; types and power of all machines; fuels; and total revenue.

Table 1 Panel A displays descriptive statistics of key variables including three measures of part-year operations: an indicator for part-year operations, the number of days worked in the year, and the number of months worked. We will focus several analyses in this paper on factories working more or less than the median number of days of the sample (240 days), similar in spirit to Dement'ev's (1897) approach, since he also relied on empirical notions of full-time operation. For most analyses in the paper, however, we use the raw number of working days. Table 1 Panel B breaks down part-year operation by industry: given the large variation in working days per year by industry, we will be mindful to include industry controls in most regressions. Panel B also demonstrates that generally more capital-intensive industries like metals and machines, cotton, and chemicals tended to operate full-year. Unsurprisingly, the least seasonal industries like paper tended to consist of factories mostly located in cities.

Figure 1 Panel A reports a histogram for the number of working days in the factory per year, which shows a lot of variation in the number of working days but some heaping, particularly at 100 days, 200 days, and 270 days, which would correspond to one season, two seasons and full-time operation. Panel B of this figure displays separate histograms for factories located in cities versus in rural areas (uezds). Urban factories tended to work more days than rural factories; a large mass of rural factories operated fewer than 250 days.

For some analyses, we also match the factories in our database to another manufacturing census that covers all of European Russia in 1900 (*List of Factories and Plants of European Russia* 1903). Factories are hand matched by name, industry, and province. The 1900 source does not record information about factories' working days per year, but we can use the source to test whether factories in European Russia that worked more days per year are more likely to survive to be recorded in the later manufacturing census.

5. Hypotheses and Empirical Methods

Our study seeks to understand Russia's industrial development at a moment in transition. We thus make two sets of predictions. First, we relate a factory's working days to observable factory characteristics, particularly location, age, capital, and labor force composition. Here we partly replicate Atack et. al. (2002) to form comparisons with the better-known United States context. Second, we consider part-year operation as a transitional feature of Russian agriculture and consider whether operating more days per year was associated with greater efficiency and likelihood of survival.

We argue that factories operated part-year primarily because of labor market constraints due to seasonal agriculture, which has several implications for how part-year factories operated. First, and most simply, factories that operated part-year will be more likely to be located in rural districts rather than cities. Because we hypothesize that part-year operation is costly, we predict that part-year operating factories will be younger, because they will tend to fail at higher rates. Full-year operating factories will be older and will thus demonstrate some survivor bias.

Furthermore, factories that operated part-year would have to leave any fixed capital idle when they did not operate. Thus, we predict a positive relationship between the number of days per year a factory works and the factory's use of powerful machines. Total working days may be related to the total machine power in the factory, since more machine power left idle is costly. Total working days may also be related to the factory's overall capital intensity, machine power per worker or per unit of revenue, if factories that operate part-year will use less capital to produce the same amount of output. If part-year operation places a constraint on the overall size of the factory, we may see an effect on the size of total capital but not capital intensity. In fact, part-year operating factories may appear more capital-intensive if they are unable to substitute labor for capital as much as they would like. Thus, we can make a strong prediction about the level of capital in the factory, but the hypothesized effect on capital intensity seems ambiguous.

Operating full-year vs part-year may also have been related to the factory's labor force composition, since part-year operation may have reflected constraints on the labor market. However, the direction of the relationship is somewhat ambiguous. Part-year factories located in the countryside may have chosen to employ women and children otherwise idle during the agricultural off-season. On the other hand, women who lived in cities may have had the opportunity to spend more time at manufacturing firms as they would have no responsibilities related to agriculture.[8] Furthermore, urban factories may have been larger and more capital intensive, which facilitates employing women and children due to division of labor[9]. Thus, interactions among urban location, size, and capital intensivity may be relevant to the relationship between labor force composition and working days.

To test these hypotheses, we first consider a series of two-sample and two-proportion hypothesis tests comparing full-year and part-year factories. Then, we consider regressions of the form:

$$\log(WorkingDays)_{ijr} = \beta_0 + \beta_1 \log(Machine\ Power + 1)_{ijr} + \beta_2 \log(TotalWorkers)_{ijr} + \beta_3 City_{ijr} + \beta_4 Age_{ijr} + \beta_5 Age_{ijr}^2 + \mu_j + \eta_r + \epsilon_{ijr}$$

This regression estimates the correlation between the number of working days in factory *i* in industry *j* and region *r* and the factory's total capital (as measured by total horsepower plus 1), its size as measured by total workers, whether the factory is located in a city, and the factory's age and age squared. We estimate the regression with OLS and with a Tobit model right-censored at 6, since $\ln(365) = 5.90$.

For comparison to the United States context, we test a set of relationships established by Atack et. al (2002), who estimate OLS regressions with log full-time equivalent months in 1870 and 1880 on the left-hand side, their measure of full-time operation. They regress log full time equivalent months on several binned measures of size, steam horsepower, log capital per worker, percentage of workers who were women and children, and location controls (Atack et. al Table 2, p. 820). They found that full-time

[8] Education presented an important outside option for relatively few Russian children in this period. According to Chaudhary et al. (2012), in 1861, 5% of the Russian school-aged population was enrolled in formal primary education. By 1911, this number had reached 20%. By comparison, this percentage stood at 71% in Hungary, 46% in Spain, 41% in Jamaica, and 30% in Uruguay c. 1910.

[9] Goldin and Sokoloff (1982) find that in the early 1800s Northeast, as firms grew in size or scale of production, so did the proportion of women and children in the workforce. They argue that was at least partially a result of division of labor, and unskilled workers, often women and children, were substituted for skilled workers, that had usually been men.

equivalent months of operation were positively correlated with urban location, employment, and capital intensivity but negatively correlated with employment of women and children and steam horsepower. The negative correlations with female and child employment and with steam power surprised the authors, but they speculate that female labor was likely less consistent over the course of the year and that children attended school during the year but remain uncertain about how to explain the relationship with steam power. We estimate similar regressions but with log working days on the left-hand side to form a comparison with the Russian case.

Next, we examine the relationship between a factory's operating time and economic performance. Factories that operated fewer days per year may have paid more fixed costs from starting up and shutting down. Thus, we expect factories that operated more days per year to produce more revenue given the same labor and capital inputs. However, given revenue is measured annually, that relationship is likely to be mechanically true. We also examine, then, whether factories that operated more days per year produced more revenue per day, with or without controlling for inputs.

Finally, we consider whether factories that operated full-year were more likely to survive to 1900. A factory survives if it appears in the 1900 factory census. We expect that factories that operated a greater proportion of the year may have been more likely to survive. Given that full-year operation may have been more productive and more profitable, part-year factories may be more likely to shut down. Broadly, due to Smithian growth, we expect more specialized full-year operating factories to become the prevailing mode of production, and hence such factories would be more likely to survive. We test whether factories that operated longer were more likely to survive using several approaches. First, we compare the proportion of full-year factories that survive to the proportion of surviving part-year factories. Second, we estimate several probit regressions, where the left-hand side variable is the probability that an 1894 factory appears in 1900.

6. Results

Our understanding of part-year operation in Russia suggests that factories that were larger, had more machine power, and were located in cities likely operated for longer periods of time within a year, because they more closely resembled formal, developed factories. Full-year factories, able to take advantage of economies of scale and less bound by the costs of idle capital, may be more productive. Regions where highly seasonal agricultural crops were an important factor of the economy, manufacturing was likely to be more seasonal than elsewhere, taking on a secondary role to agriculture. Finally, full-year operating factories were likely to survive longer than part-year factories. We now present results addressing each of these claims.

6.1. Firm Characteristics and Operating Time

This section presents what we can learn about the relationship between factory characteristics and operating time from our newly-collected, highly detailed factory micro data. These new data allow us to address longstanding concerns in the literature about the relationships between working days and capital accumulation, factory size, and labor force composition.

Table 2 documents a set of compelling differences between factories that operated full-year and those that operated seasonally. Factories that operated 240 days per year or more tended to have more powerful machines, to have more workers, to be older, and to employ a greater number of women and children. Since full-year factories tended to have larger workforces, factories operating fewer than 240 days have more machine power per worker. Furthermore, full-year factories may have only employed more women and children because their overall workforces were larger. But full-year factories did employ larger proportions of women and children out of their total workforces. Full-year factories were also more likely to be located in cities. Each of these results, however, describes unconditional means. Size is likely correlated with urban location, for example, so full-year factories might only be larger because they were located in cities. We thus proceed to regression models, which allow us to introduce relevant controls for size, industry, and location and to investigate other simultaneous relationships.

We present regressions describing a factory's days of operation in Table 3. Most columns present tobit regressions right-censored at ln(365), though we also include one OLS regression for robustness. Column 1 presents an unconditional regression of log working days on machine power, and we find a strong, positive relationship. Factories that operated more days per year tended to possess more total machine power. The next column introduces additional independent variables, log workers and age, along with controls for industry and region. In line with our predictions, we find that machine power, labor, and urban location are positively related to working days of a firm. The OLS regression presented in Column 3 demonstrates the same relationships.

Table 3 also includes our replication of the Tobit model employed by Atack et. al. (2001), which regresses operating time on measures of size, capital intensivity, steam power, female and child employment, and location. Our findings, reported in Columns 4 through 7, mirror their results closely: log working days is positively related to size and urban location. However, we find that steam horsepower and employing women and children are positively related to working days per year. The negative coefficient on steam horsepower deviated from their original hypotheses; we likely are able to distinguish the effect of steam power more clearly given the greater variation in working days compared to their measure of full-time equivalent months.[10] Also, they had found a negative relationship between working days and female or child employment, which they speculated could be due to female preferences for "lumpy" downtime and children's school attendance.[11] The labor market for women and children was likely markedly different in Russia. Few children, for example, attended school.

6.2. Firm Characteristics, Productivity, and Survival

[10] However, in their regressions, the coefficient on steam horsepower turned positive when they used log annual hours, a more variable measure, as their dependent variable.
[11] Atack et. al (2001), p. 802.

If full-year operation is more efficient than part-year operation, factories that work more days per year should be more productive. In this section, we test whether a factory's number of working days is correlated with productivity, measured three ways: revenue per worker, total factor productivity (calculated as the residual of a log Cobb-Douglas production function), and revenue per day. It may be the case that more efficient factories operate for longer durations or that efficient and operating time are determined simultaneously, so we do not stress a particular causal direction.

Table 4's first three columns examine the relationship between productivity and working days. All three columns include controls for region, industry, factory age and age squared, and whether the factory is located in a rural or urban location. Still, factories that operate for more working days are more productive, whether productivity is defined as revenue per worker, total factor productivity, or working days per year.

The final column investigates whether the relationship between revenue per day and working days can be explained by inputs, especially by capital. This column regresses log revenue per day on total working days, total machine power, total workers, an interaction between total machine power and working days, and controls for urban location and age. Given the input controls, the relationship between overall working days and revenue per day appears negative. However, the coefficient on the interaction between total machine power and working days is positive and significant: factories with more machine power that work more days per year have more revenue per day.

We thus proceed by testing whether factories that operated more days per year were more likely to survive to 1900 than factories that operated seasonally. As Russia industrialized, fewer factories likely operated part-year, because part-year operation was less efficient. This decrease in the numbers of part-year operating factories could arise from either the intensive margin (factories operating more days per year) or the extensive margin (part-year factories disappearing at higher rates). Our results show that, indeed, full-year factories were more likely to survive to 1900.

Table 5 Panel A displays survival rates from the 1894 to the 1900 manufacturing census both overall and broken down by full-year vs. part-year operation. Because the 1900 census only includes factories located in European Russia, these results exclude 1894 factories located outside European Russia. Overall, 34.51 percent of factories in the 1894 census are able to be matched to the 1900 census. 45.40 percent of full-year operating factories and only 23.11 percent of part-year factories survived, a large difference.[12] Panel B presents estimates of probit regressions, which allow for the introduction of additional controls. These regressions only include 1894 factories, where the dependent variable is the probability of survival to 1900. Column 1 reports an unconditional regression, Column 2 includes industry and region controls, and Column 3 includes log Revenue per Worker to discern in part whether survival differences are entirely due to differences in labor productivity. In all three columns, log working days is strongly and positively related to factory survival to 1900, even when log revenue per worker is included.

6.3. Female Employment

Here we more closely examine the correlates of female employment as a proportion of a factory's total workforce. Table 6 column 1 shows that female employment is positively related to operating more than median number of days (240 days) and to urban location. The regression also includes an interaction term, to examine whether full-year-factories located in cities are more or less likely to employ women than full-year factories in the countryside. However, in this regression, no difference is apparent. Column 2 introduces controls for the factory's age and age squared as well as industry and region controls. The results are much the same as those presented in Column 1: factories operating full-year and in urban locations were more likely to employ women.

Column 3 adds an important independent variable: capital intensity, as measured by a factory's machine power per worker. Here, the coefficient on the urban dummy loses statistical significance, and the coefficient on capital intensity is negative and highly statistically significant. When capital intensivity is measured as the log of total power (plus one) divided by total workers, more capital intensive factories

[12] A two-proportion z-test produces a test statistic of z = 27.0184.

employ fewer women as a percentage of the total labor force.[13] This result would contradict a model in which female employment increases as the division of labor is facilitated by the use of more machines per person. However, in Column 4, we see that the proportion of women employed in factories increases in total machine power. Perhaps, then, a factory's total machine power, rather than its tendency to substitute capital for labor, best predicts the kind of Smithian division of labor that would permit greater female employment.

Finally, Columns 5 and 6 present estimates of similar regressions using Tobit models left censored at 0, since many factories employed no women at all. Here, we see that operating full-year was associated with employing women. Also, factories located in cities were more likely to employ women, factories located in cities that operated full-year were somewhat less likely to employ women compared to rural full-year operating factories. Perhaps, in the countryside, employing women allowed factories to operate full-year. Similarly to the results presented in Columns 3 and 4, capital intensity was associated with employing fewer women, but factories with greater total machine power employed a larger proportion of women.

6.4. Types of Agriculture and Firm Operation Time

In regions where a substantial portion of agricultural output were major crops such as wheat and corn, and in cases when such crops were highly seasonal, most prominently wheat, would hypothetically be most likely to hold on to the seasonal manufacturing operation, diverting labor to agriculture as needed. Sokoloff and Dollar (1997) show in regions where grains were more economically important, labor was more likely to be diverted into agriculture, because of the high opportunity cost of opting out of agriculture during busy seasons.

We thus test whether the relationship between grain agriculture and seasonal factory work characterized Imperial Russian factories. Two additional datasets permit us to examine these

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[13] This inverse relationship between female employment and log (K+1/L) holds even in an uncontrolled simple regression.

relationships: the Electronic Repository for Russian Historical Statistics (RISTAT) compiled by Kessler and Markevich (2014), which we used to aggregate wheat output in kind per province in year 1897; and the Ministry of Finance Yearbook data from 1900, which provides the area of each province, total population, and urban population. We assume that 1897 wheat production closely resembles wheat production in 1894 (the year described by our manufacturing data). Similarly, we assume that the 1900 area and population statistics sufficiently approximate these statistics in 1894.

For province p, we estimate:

$$\text{WorkingDays}_p = \beta_0 + \beta_1 \log(Wheat\ Ratio)_p + \beta_2 \log(Population\ Density)_p + \beta_3 \log(Urban\ Ratio)_p + \epsilon_p$$

Wheat and population density are defined as total wheat output and population divided by total area, respectively, while urban ratio is urban population divided by total population. ϵ_p is the error term. Working Days is the average number of working days in each factory in the province. Unlike the regressions reported in the rest of the paper, we use total working days rather than the log of total working days, because in the aggregates, the distribution of log working days is very oddly shaped.

We report the results in Table 7. The first three columns regress total working days on each of the three right-hands side variables individually. In Column 1, we see that higher proportion of wheat production on land results in fewer working days of a firm; but the result is very noisy. Columns 2 and 3 show that total working days increases in more population dense and more urban provinces, though only the result for the proportion of the population living in cities is statistically significant. Finally, in Column 4, we see some evidence that total working days decreases in the wheat ratio when we control for population density and urbanization: specifically, one percent increase in wheat to area ratio would have resulted in more than 3 day decrease in firm working days in that province. These findings are consistent with our initial hypothesis that the provinces most dependent on grains, specifically wheat, were slowest to adopt the industrial factory model. However, these results should be taken with a large grain of salt given the sensitivity of these results to functional form and included controls.

7. Conclusion

Late-nineteenth century Russian factories provide a snapshot of modernization in progress. Factories located outside of urban labor markets were more likely to shut down during part of the year, and those factories that only operated during part of the year produced output differently than those that operated full-time. Part-year factories were less likely to survive in the long run, suggestive evidence that full-year operation would become the more dominant mode of production.

Russian factories at this moment thus demonstrated a tendency to transition to a more efficient, more capital-intensive mode of production in increasingly formal, specialized factories, much like establishments in the United States or Great Britain had at an earlier point in time. Far from approaching some stagnant plateau, even after most rapid period of growth in the 1880s, the Russian Empire's industrial sector was growing, changing, and modernizing rapidly.

In this fascinating context, many important questions remain, and much still remains unquantified. Economic historians have not yet undertaken a comprehensive study of the relationship between Russia's primarily agricultural economy and the development of its industrial factories. How, for example, did shocks to the agricultural labor market affect the production technology employed by factories? Studies along this dimension could shed light on some of the most debated questions in Russia's economic history.

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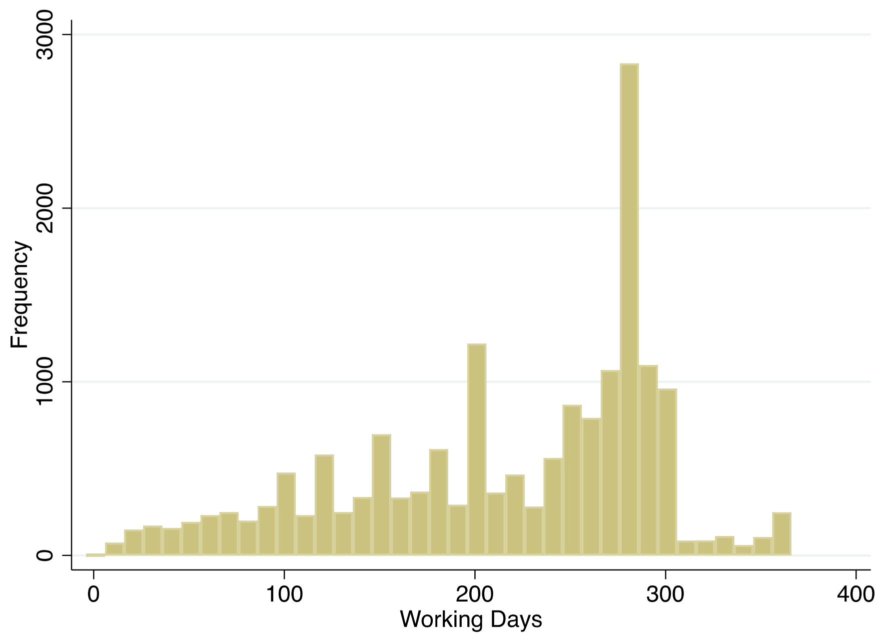
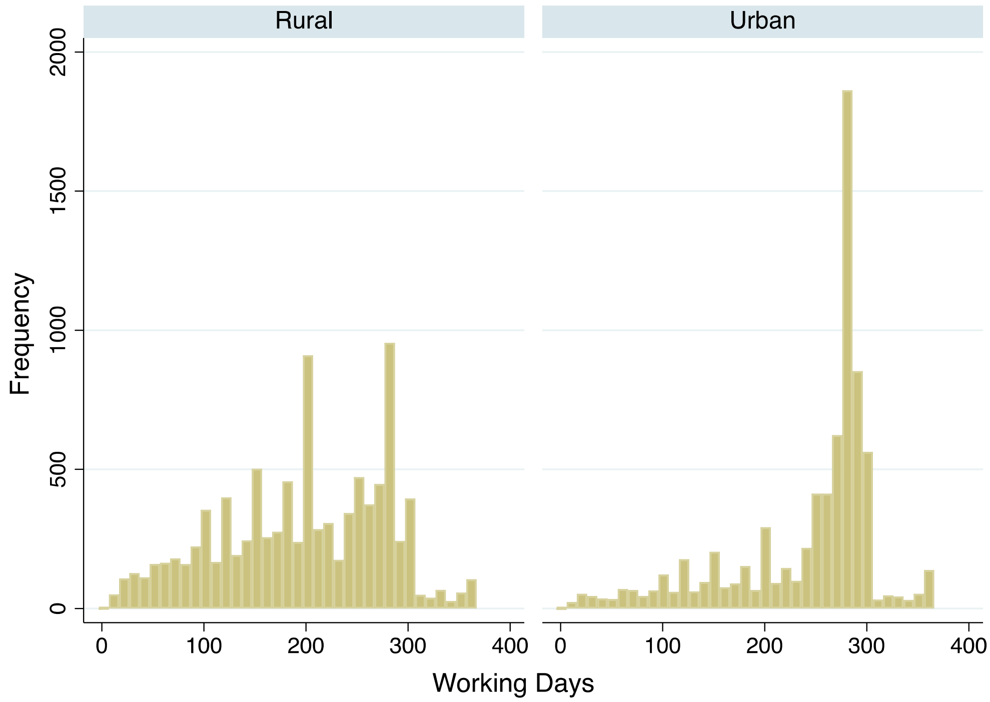
Figures

Figure 1: Histogram of Total Working Days

Panel A: All Factories



Panel B: Histograms by Rural and Urban Location



Source: Imperial Russian Manufacturing Database (Gregg 2019).

Tables

Table 1: An Overview of the Factory Data and Operation Duration

Panel A: Descriptive Statistics

	N	Mean	Med.	Standard Dev.	Min.	Max.
Working Days	17,082	215.70	240.00	80.23	1.0	365
Operated >=240 days	17,082	0.52	1.00	0.50	0.0	1
Total Machine Power	17,512	35.16	3.00	194.19	0.0	8,242
Age	14,112	20.25	14.00	20.73	0.0	262
Urban	17,512	0.43	0.00	0.50	0.0	1
Employed Women	17,512	0.25	0.00	0.43	0.0	1
Employed Children	17,512	0.09	0.00	0.28	0.0	1
Number of Women	17,512	13.80	0.00	103.79	0.0	3,643
Number of Children	17,512	1.15	0.00	8.96	0.0	341

Panel B: Frequency, Age, Location, and Operation Duration by Industry

Industry	Observations	Average Firm Age (Years)	Percentage Urban	Proportion Operating >=240 Days	Mean Working Days
Animal	1,785	25.261	0.565	0.633	226.782
Chemical	731	17.155	0.480	0.643	236.447
Cotton	665	25.035	0.367	0.591	226.845
Flax	365	22.952	0.474	0.338	198.708
Foods	7,556	19.257	0.292	0.354	194.222
Metals and Machines	1,511	21.489	0.742	0.863	262.566
Mineral Products	1,272	20.354	0.359	0.351	186.166
Mixed Materials	421	16.526	0.724	0.720	245.812
Paper	850	20.911	0.813	0.903	275.837
Silk	269	17.343	0.301	0.440	223.463
Wood	1,007	13.624	0.446	0.480	207.855
Wool	1,080	18.892	0.486	0.758	246.140
Total	17,512	20.249	0.434	0.517	215.702

Notes: 240 days represents the median number of factory working days in the dataset. *Total Machine Power* presents the total amount of horsepower in a firm. Source: Imperial Russian Manufacturing Database (Gregg 2019).

Table 2: Operation Duration and Firm Characteristics

Variable	Operating More Than 240 Days	Operating Fewer Than 240 days	Test Statistic
			Two-Sample t-test, |t|
Total Machine Power	52.18 (2.85)	18.23 (0.56)	11.3296
Total Workers	95.43 (3.86)	29.91 (0.87)	16.0418
Total Machine Power Per Worker	0.83 (.027)	1.31 (0.033)	11.1816
Age	21.99 (0.25)	18.45 (0.24)	10.0709
Number of Women Employed	24.09 (1.54)	3.44 (0.20)	12.8990
Number of Children Employed	1.93 (0.13)	0.34 (0.032)	11.3470
Women Employed / Total Workers	0.10 (.0021)	0.056 (.0017)	16.4433
Children Employed / Total Workers	0.021 (0.00082)	0.0096 (0.00065)	11.1783
			Two-Proportion z-test, |z|
Urban	0.60 (0.0052)	0.26 (0.0049)	43.9120

Notes: 240 days represents the median number of factory working days in the dataset. Total Machine Power measures the total amount of horsepower in a firm. Standard errors in parentheses. Source: Imperial Russian Manufacturing Database (Gregg 2019).

Table 3. Firm Characteristics and Operating Time

	Dependent Variable: Log (Working Days)						
Model:	Tobit	Tobit	OLS	Tobit	Tobit	Tobit	Tobit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log (Total Machine Power + 1)	0.023***	0.009***	0.009***				
	(0.002)	(0.003)	(0.003)				
Log Workers		0.058***	0.058***		0.066***		
		(0.004)	(0.005)		(0.004)		
City		0.167***	0.167***	0.181***	0.160***	0.178***	0.178***
		(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Age		0.003***	0.003***	0.004***	0.003***	0.004***	0.004***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age Squared		-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
100 < workers < 500				0.050***		0.053***	0.049***
				(0.017)		(0.016)	(0.017)
workers > 500				0.061*		0.093***	0.061*
				(0.034)		(0.030)	(0.034)
Steam Power / 100				0.006**	-0.006**		0.006**
				(0.003)	(0.003)		(0.003)
% of Women & Children				0.002***	0.001*	0.002***	0.001***
				(0.000)	(0.000)	(0.000)	(0.000)
Log [(K+1)/(L)]						-0.004	-0.005
						(0.003)	(0.003)
Constant	5.222***	5.032***	5.032***	5.135***	5.017***	5.138***	5.131***
	(0.006)	(0.036)	(0.036)	(0.036)	(0.037)	(0.036)	(0.036)
Observations	17,082	13,673	13,673	13,523	13,523	13,673	13,523
Industry Controls	NO	YES	YES	YES	YES	YES	YES
Regional Controls	NO	YES	YES	YES	YES	YES	YES
R2 or Pseudo R2	0.00305	0.107	0.165	0.0939	0.107	0.0937	0.0940

Notes: *** p<0.01, ** p<0.05, * p<0.1. Source: Imperial Russian Manufacturing Database (Gregg 2019). Standard errors in parentheses. The outcome variable is the log of the factory's number of working days. The Tobit model in all regressions is right censored at 6, because log(365) is approximately equal to 6. Log (K+1)/L is the log of total machine power plus one divided by Total Workers.

Table 4. Correlates of Operation Duration and Revenue per Working Day

Model	OLS	OLS	OLS	OLS
Dep. Variable	Log (Rev/ Worker)	TFP	Log(Rev/ Day)	Log (Rev / Day)
	(1)	(2)	(3)	(4)
Working Days	0.0049***	0.0046***	0.0018*	-0.0027***
	(0.0004)	(0.0004)	(0.0011)	(0.0005)
Log (Machine Power +1)				0.0511
				(0.0383)
Working Days * Log (Machine Power + 1)				0.0005***
				(0.0001)
Log Workers				0.9358***
				(0.0264)
City	0.2187***	0.3395***	0.4367***	0.3445***
	(0.0566)	(0.0484)	(0.1059)	(0.0531)
Age	0.0024**	0.0025**	0.0221***	0.0023*
	(0.0011)	(0.0011)	(0.0032)	(0.0013)
Age Squared	-0.0000	-0.0000**	-0.0001***	-0.0000*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Constant	6.0673***	-0.6188***	3.3882***	2.4441***
	(0.2497)	(0.2100)	(0.3931)	(0.2510)
Observations	12,470	12,470	12,594	12,470
Industry Controls	YES	YES	YES	YES
Regional Controls	YES	YES	YES	YES
R2 or Pseudo R2	0.301	0.279	0.128	0.722

Notes: *** p<0.01, ** p<0.05, *p<.10. Source: Imperial Russian Manufacturing Database (Gregg 2019). Standard errors clustered by Industry-Region groups in parentheses.

Table 5: Factory Working Days and Survival to 1900

Panel A: Factory Survival and Part-Year Operation (European Russia Only)

	All Factories in European Russia	<240 days	>=240 days
Number of Factories in 1894	16,642	1,881	14,761
Number of Factories that Survive to 1900	5,378	279	5,099
Survivors to 1900 / Factories in 1894	0.3232	0.1483	0.3454

Panel B: Probit Regressions: Probability of 1894 Factory to Appear in 1900 (European Russia Only)

	(1) Probit	(2) Probit	(3) Probit	(4) Probit
Log (Working Days)	0.644***	0.517***	0.306***	0.401***
	(0.027)	(0.028)	(0.032)	(0.046)
Log (Revenue per Worker)			0.211***	
			(0.014)	
TFP				0.150***
				(0.020)
Constant	-3.882***	-3.144***	-3.588***	-2.538***
	(0.145)	(0.175)	(0.201)	(0.285)
Observations	16,230	16,230	11,928	7,352
Industry Controls	NO	YES	YES	YES
Regional Controls	NO	YES	YES	YES
Age Controls	NO	NO	YES	YES
Pseudo R2	0.0438	0.133	0.140	0.183

Notes: *** p<0.01, ** p<0.05, *p<0.10. Source: Imperial Russian Manufacturing Database (Gregg 2019). Robust standard errors in parenthesis. Regressions estimate the probability that an 1894 factory appears in the 1900 database. TFP in Column 4 is the residual of a log Cobb Douglas production function that includes total workers and total machine power as inputs.

Table 6. Correlates of Female Employment

Dependent Variable:	Women/(Total Workers)					
	OLS	OLS	OLS	OLS	Tobit	Tobit
	(1)	(2)	(3)	(4)	(5)	(6)
Operated >=240 days	0.041***	0.023*	0.024**	0.020	0.095***	0.069***
	(0.013)	(0.012)	(0.012)	(0.012)	(0.012)	(0.013)
City	0.028**	0.024**	0.017*	0.026**	0.045***	0.088***
	(0.011)	(0.010)	(0.009)	(0.010)	(0.015)	(0.015)
Operated >=240 days * City	-0.009	-0.005	-0.013	-0.004	-0.037*	0.001
	(0.016)	(0.015)	(0.015)	(0.014)	(0.019)	(0.019)
Age		0.000	-0.000	-0.000	0.001*	0.001**
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age Squared		-0.000	0.000	-0.000	-0.000	-0.000**
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log [(K+1)/L]			-0.017***		-0.065***	
			(0.003)		(0.003)	
Log (Machine Power +1)				0.007***		0.033***
				(0.002)		(0.003)
Constant	0.048***	-0.053	-0.068**	-0.057	-0.849***	-0.782***
	(0.012)	(0.033)	(0.032)	(0.034)	(0.045)	(0.044)
Observations	16,797	13,673	13,673	13,673	13,673	13,673
R-squared	0.020	0.223	0.241	0.227	0.270	0.251
Industry Controls	NO	YES	YES	YES	YES	YES
Regional Controls	NO	YES	YES	YES	YES	YES

Notes: *** p<0.01, ** p<0.05, *p<.10. Source: Imperial Russian Manufacturing Database (Gregg 2019). Standard errors clustered by Industry-Region groups in parentheses. Log (K+1)/L is the logarithm of total machine power plus one divided by total workers.

Table 7: Wheat Production and Working Days

OLS				
Dependent Variable:	Total Working Days			
	(1)	(2)	(3)	(4)
Log (Wheat/Area)	-2.040*			-3.322***
	(1.204)			(1.112)
Log (Urban/Population)		19.65***		19.36***
		(5.877)		(5.449)
Log (Population/Area)			1.851	2.590
			(2.464)	(2.810)
Constant	201.5***	247.5***	206.7***	247.5***
	(3.439)	(13.19)	(4.783)	(11.47)
Observations	72	79	79	72
R-squared	0.027	0.136	0.007	0.213

Notes: *** p<0.01, ** p<0.05, * p<0.1 Sources: Imperial Russian Manufacturing Database (Gregg 2019) and Kessler and Markevich (2014). The outcome variable is the number of working days of a firm. Robust standard errors in parentheses.