Is High-Tech Care in a Middle Income Country Worth It? Evidence from Perinatal Centers in Russia

By Dzhamilya Nigmatulina[†], Charles Becker[‡]

How much does a dramatic increase in technology improve healthcare quality in an upper-middle income country? Using rich vital statistics data on infant and maternal health outcomes, this study evaluates the effect of introducing technologically advanced perinatal hospitals in 24 regions of Russia on infant mortality during the period 2009-2013. A 7-year aggregate panel dataset reveals that opening a perinatal center corresponds to infant mortality reduction by 3.8% from the baseline rate, neonatal (0-28 day) mortality by 7% and early neonatal (0-6 day) mortality by 7.3%. We find that the perinatal centers help to save 263 additional infant lives annually, ranging from 3 to 25 lives in regions with different birth rates. We further estimate an annual average cost of 52 mln rb (or 2.6 m 2014 PPP USD) per life saved in an average region, which is much higher than the cost from similar interventions in the US.
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At the beginning of *perestroika*, the Soviet government revealed that infant mortality in the USSR was 3 to 5 times higher than in most countries in Western Europe. Today the gap has narrowed, yet Russian infant mortality (8.7 per 1000 births in 2012) remains higher than in Hungary, Czech Republic and Latvia. A more narrow definition of a live birth than the EU countries prior to 2012 aggravates this situation and results in many fewer infant deaths recorded in Russian official statistics.[1]

Poor international rankings together with shrinking population have motivated the Russian government to increase its investment in improving demographic indicators. In December 2007 some 19 billion rb (or 471 million 2014 USD) (Ministry of Healthcare of the Russian Federation, 2008) were invested from federal funds into building one perinatal

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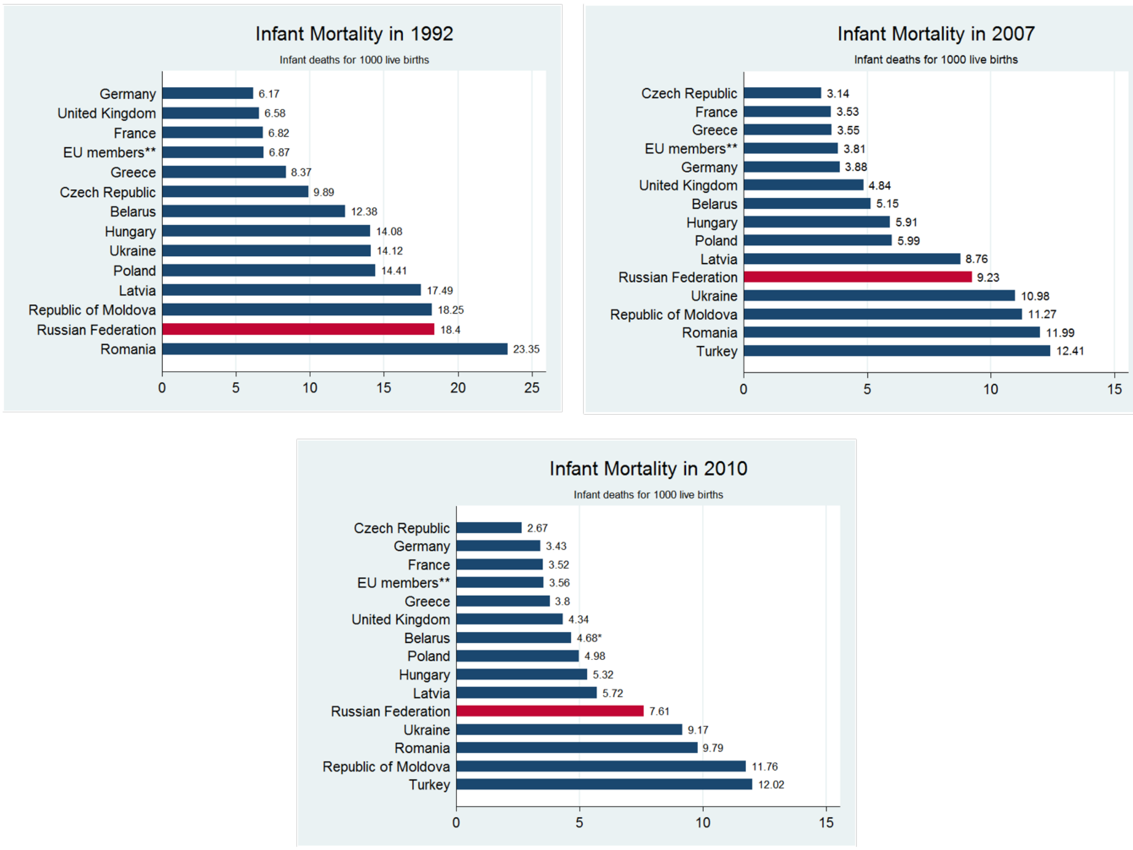
† Nigmatulina: London School of Economics, d.nigmatulina@lse.ac.uk.

‡ Becker: Duke University, cbecker@econ.duke.edu.

[1] Russia and previously the USSR imposed a restriction on weight and gestational period for regarding a birth as live-born, which meant eliminating the most risky cases from the statistics; many other countries have never imposed restrictions and consequently have had higher reported infant mortality rates.

Figure 1. European Rankings of Infant Mortality



Note: ∗ Belarus value is from 2009. ∗∗ The member states that were part of the European Union by 2004.

Source: World Health Organization Europe.

center in each of 23 (out of 83) Russian regions as part of the National Health Project; one more center was built in Omsk province (oblast) in the same period solely funded by the local budget.[2] Each centrally-funded hospital required a contribution of 10%-50% from the local government (Minister of Healthcare Veronika Skvortsova, quoted in *Rossiiskaya Gazeta* on May 5th, 2013). Most centers opened in late 2010 and late 2011. They were placed in oblast capitals and the citizens of the region were entitled to free services if a mother had sufficient risk of a complicated delivery.

These state-of-the-art hospitals were intended to provide intensive care for births with complications, premature births, and other conditions for which a standard hospital or

[2]The centers co-financed by the federal funds were Blagoveshchensk, Volgograd, Voronezh, Irkutsk, Kemerovo, Kaliningrad, Kirov, Krasnodar, Krasnoyarsk, Kurgan, Kursk, Perm, Rostov-on-Don, Ryazan, Saratov, Saransk, Tver, Tomsk, Chita, Yaroslavl, Murmansk, Sverdlovsk and Saint-Petersburg.

maternity unit did not have the requisite facilities. Most importantly, each of the perinatal centers was equipped with a Neonatal Intensive Care Unit (NICU) with high-tech machinery for resuscitating prematurely born infants. The mechanism of mortality reduction works via re-routing of potentially risky deliveries from regional maternity hospitals to these centers (Sukhanova, 2012), thereby increasing the probability that an infant under risk gains access to advanced infrastructure, and specifically to NICU units.

The investment was carried out without rigorous economic evaluation of its potential outcomes. How much did health improve from the perinatal centers alone and was it worth it? We attempt to answer this question in our study. If the centers are shown to improve health outcomes, which are proxied by newborn mortality rates, we expect to find a reduction in infant mortality overall and especially in neonatal mortality (age 0-28 days) and early neonatal mortality (age 0-6 days), since the survival of at-risk infants in the very early ages is most dependent on availability of equipment (Cutler and Meara (2000)). Indeed, we find that the highest proportional reduction in mortality was for the 0-6 day category (7.3% from the baseline), less for 0-28 day category (7% from the baseline rate) and that there was almost no effect for the 28-365 day category.

The relevance of our study is not limited to the economic evaluation of this single policy. While technology-intensive investments such as NICUs have been shown to be life-saving, the cost of each life saved is a matter of hot debate (Cutler and Meara (2000); Almond et al. (2010); Almond and Doyle Jr (2011); Cutler et al. (1998)). Moreover, although there is a large body of literature estimating the returns to technology-intensive spending in first-world countries, like the US, and returns to basic investments in developing countries, like Tanzania, the evidence regarding these returns in middle-income countries is quite limited. Further, by focusing on a middle income country, we benefit from evaluating the setting where the entire population has access to basic elements of care, but often limited access to advanced care: in high income countries near universally good health outcomes make it difficult to identify the effect of technology investments, whereas in low income countries it is hard to separate the effects of healthcare access expansion and technology itself.

On one hand, we may expect to find higher returns than in the US, as there is less medical infrastructure at baseline. On the other hand, bottlenecks, such as a low supply of doctors, or poor healthcare organization and infrastructure may impede the realization of technology in full.

We believe that our choice of data and sample can give an important and informative estimate for the returns to costly medical advances in a middle-income country. First, advanced low birth weight infant care is expensive. Cutler and Meara (2000) quote a cost as high as $3,500 per infant per day in a NICU in the US; ultimately, this can sum to as much as $1 million for a prolonged stay. Second, in middle-income countries newborns' outcomes reflect both the state and changes of the healthcare system and span all income and education groups of the population, as births outside of hospitals comprise only 0.16 % in Russia today (2013). Third, for extremely and low birth weight outcomes the probability of survival almost fully depends on the availability of technology (Paneth (1995), Williams and Chen (1982), Muraskas and Parsi (2008)), whereas for other outcome variables such as tuberculosis rates or occurrence and mortality of cardiovascular diseases, it difficult to distinguish the relative roles of income, lifestyle, and doctor's qualifications.

Finally, the introduction of perinatal centers with NICU's across so many locations and in such a short time is unprecedented. The perinatal centers opened within a sufficiently short period (1-4 years) that many other aspects such as the composition of the population, organization of care, and number of at-risk infants born annually could not have changed much. Thus, our data allow us to estimate the marginal returns to the change in medical technology (rather than the average return over a long period of time). The remaining, more sensitive, factors include a possible increase in the number of doctors, and a "substitution effect" whereby the new centers possibly could have detracted resources from other facilities in the region. We explore these concerns by measuring closures of basic obstetrics hospitals and maternity units. We further account for potential increases in the number of neonatologists in the treated regions and attempt to estimate the heterogeneity of outcomes from different supply thereof.

We also face and address a second methodological challenge, when some treatment coincides with the change in birth accounting in 2012. Although the change was country-wide, the response to the change could have been different depending on whether the region was treated or not. By using data birth by birthweights and the proportion of "late abortions", we check whether the response to the accounting policy was significantly different in the treated regions vs. untreated and confirm that this was not the case.

In December 2013, Russian Ministry of Health initiated a program to build 32 additional perinatal centers in 30 Russian regions at the cost of 53 billion rb (1.277 billion 2014 USD) to the federal budget (Ministry of Healthcare of the Russian Federation, 2013).[3] As before, no sufficient comparative analysis was conducted as to the effectiveness of this vast expenditure on health outcomes. Moreover, it is overwhelmingly likely that other large health infrastructure projects are also under contemplation, in Russia and elsewhere, with little reliance on serious effectiveness assessments. Our study provides both a template of how to analyze these investments and an estimate of what to expect from them.

The paper is organized as follows. Section I provides background on Russian mortality accounting, Section II reviews prior relevant literature on returns to healthcare investment, Section III briefly outlines the mechanism of technology reducing mortality, Section IV describes the data and analysis sample, Section V outlines the empirical model and validity checks, Section VI presents results, and Section VII concludes.

[3]The selected cities (all regional capitals) are Arkhangelsk, Belgorod, Bryansk, Kaluga, Lipetsk, Nizhny Novgorod, Orenburg, Penza, Pskov, Samara, Sakhalin, Smolensk, Tambov, Ulyanovsk, Chelyabinsk, Stavropol, Krasnodar, Barnaul (Altaiskiy kray), Ulan-Ude (Republic of Buryatia), Ufa (Bashkortostan), Makhachkala (Dagestan), Magas (Ingushetia), Nalchik (Kabardino-Balkaria), Petrozavodsk (Republic of Karelia), Yakutsk (Republic of Sakha-Yakutia), Abakan (Republic of Khakassia), Moscow, 2 centers in Krasnoyarsk, 1 center in Leningradskaya oblast' and 2 centers in Moscovskaya oblast'.

I. Background

A. Perinatal Care in Russia

Every Russian woman in childbirth is entitled to free care during delivery regardless of the type of hospital, be it high or basic, at which she presents herself. She will be referred for delivery in a perinatal center if she is designated as at risk for a complicated delivery. Perinatal centers on average hosted 22.9% of all births in the country in 2012 [4]. A perinatal center mainly differs from any other obstetrics facility by being equipped with an NICU and providing the latest available technologically intensive care for infants. Even before the expansionary policy was enacted, perinatal centers targeting complicated deliveries existed in 54 regions, but they generally were not as technologically advanced as the new ones (we later test whether the presence of a perinatal center in the region yields a different result than if the high-tech facility is introduced for the first time).

B. Mortality Statistics in Russia

Until 2012, Russia had higher gestation time and birth weight thresholds for reporting life and stillbirths than in most European countries. Such rules not only meant reporting lower infant deaths than would have been the case under conventional WHO definitions, but it also made it fairly easy to recategorize some marginal delivery cases into groups that were less significant for national statistics (stillbirths) or not accounted at all by official statistics ("late abortion" or "miscarriage").

In 2012 the official threshold for registering a birth as a "live birth" was moved from the 1000g minimum weight and 28 weeks minimum gestation down to 500g and 22 weeks, respectively.[5] Naturally, these changes caused the reported mortality to rise (as shown in Figures A3 and A4). As for misreporting (due to category transfers), it is likely to have shrunk, but potentially remained an important concern just around the new threshold: marginal births at 22-23 weeks of pregnancy (or births of live infants weighing 500-700g) may now be recorded as "late abortions". Details of definitional changes and likely impacts on recorded values are provided in Appendix A. Another type of undercounting may have become widespread in the meantime: at any weight or gestational age fragile infants who die very soon after birth may often be characterized as stillbirths, since stillbirths is a statistic less scrutinized by domestic and international public health officials.

Undercounting is only a threat to validity in our difference in difference design if the response to change in measurement standards differs across treatments and controls. We thus need to focus on differences and dynamics of the undercounting in each region to ensure it does not affect the validity of our results. The concern may arise if, for example, obstetricians in the treated region are directed to misrecord infant deaths in order to show the improvements attributed to the perinatal center. We run diagnostic regressions in section VI.D to identify this type of behavioral response of the officials, and rule it out.

[4]Starodubov and Sukhanova (2013)

[5]see Appendix A for a more detailed description of the exact changes affecting the accounting rules.

II. Prior Literature

Interventions that save infant lives can vary greatly in their costs and their effectiveness, depending on the baseline level of health and the intensity of the investments. The literature to date concentrates primarily on costly high-tech interventions in the US and low-cost interventions in developing and middle-income countries (or historical data for developed countries)[6].

The low-cost interventions included training traditional birth attendants to refer riskier patients to hospitals and performing basic tasks in Tanzania (Gill et al., 2011), training male nurses in India (Bang et al., 1999), improved sanitation of water facilities for Native American populations (Watson (2006)), and a Danish home-visiting program in the late 1930's (Wüst, 2012), all of which were shown to reduce infant mortality on the order of 40-65%. Some low-cost interventions also have been implemented in middle-income countries; analyses find moderate to high reductions in mortality, and high cost effectiveness of these reductions. Nizalova and Vyshnya (2010) estimate how the "Mother and Infant" program in Ukraine, which involved training the obstetrics personnel and changes in practices, has reduced infant mortality rate by 3.13 deaths per 1000 births (23% from the baseline rate). Galiani, Gertler and Schargrodsky (2005) argue that cleaner water from privatization of water facilities saved infant lives in Argentina. New investments and expansion of services led to improved sanitation and reduced first-month mortality by 8% compared to the baseline mortality rate in 1990. All these interventions are likely to save lives of healthy infants who have normal birth weights and are not born pre-term (for example, water sanitation only eliminates deaths from parasitic diseases caught by otherwise healthy infants). These interventions would likely be unimportant for the prematurely born, because low birth weight infants are likely to die in the first day or week without the availability of an NICU. Thus, the target group examined here is not covered, to our knowledge, in any of the previous literature on middle-income and developing countries.

High-tech intervention studies are concentrated in the US and are related to the analysis of the returns to healthcare spending. The US literature shows two common findings. Cross-sectional studies of American regions tend to indicate small or no effects of the incremental spending in technology (Baicker and Chandra (2004), Grumbach (2002), Almond and Doyle Jr (2011), Goodman et al. (2002), Finkelstein and McKnight (2008)), or at most moderate evidence from (Fisher et al., 2003), Almond et al. (2010), Doyle (2011)), whereas studies concentrating over large time periods demonstrate large benefits to technologically intensive and costly interventions (Cutler and Meara (2000), Cutler and McClellan (2001), Schwarcz et al. (2000), Luce et al. (2006)).

An explanation for the large difference in cross-section and time series results is that there may be a difference between new technologies substituting for old ones, a "treatment substitution effect", and more people being treated by existing technologies, a "treatment expansion effect", (Cutler and Meara, 2000). Medical innovation shifts the healthcare

[6] Mangham-Jefferies et al. (2014) provides a comprehensive review of studies on delivery care interventions in developing countries.

production curve outward, whereas medical intensity moves along an existing curve. Once a health innovation is introduced and shown to be better in some cases than the old procedures, it is adopted widely in the healthcare system. As the new procedure is adopted, the cross-section would not demonstrate markedly better outcomes, because even the lowest spending region had adopted until its marginal returns are zero ("flat of the curve"), which seems to be the case in the US for many procedures (Baicker and Chandra, 2011). In contrast, each large intervention in healthcare practices shifts the country-wide curve outward and we see large positive returns over many years (Fuchs, 2004). Cross-sectional or short-term panel data studies in a middle-income country may show higher returns to investment, as the healthcare spending is likely to lag further from the "flat of the curve".

An alternative explanation for no effects in the US cross-sectional findings is offered by Evans and Garthwaite (2012). By estimating heterogeneous effects from minimum length of stay legislation they point out that the returns to care for an average patient might be low in the US, as medical care intensity is already at a high level. However, if only the patients in need are considered, the returns to additional care may increase greatly. The heterogeneity of benefits is also emphasized in Wehby et al. (2009)). Gamper-Rabindran, Khan and Timmins (2010) suggest a utilization of a quantile regression to estimate heterogeneity of benefits for regions at different percentiles of mortality, rather than just the mean.

Cutler and McClellan (2001) consider both treatment expansion and treatment substitution when they evaluate returns to new technologies used to treat heart attacks, low birth weight infants, depression, cataracts and breast cancer diagnosis. They demonstrate a very large positive return to catheterization and to technologies introduced in the 1990's to treat LBW infants, while breast cancer screening had an indeterminate effect. Cutler, Rosen and Vijan (2006) show that the cost of year of life saved has increased from $7,400 to $36,600 during the period 1960-2000, which still yields a positive return, as the commonly cited social value for a statistical year of life gained is $100,000 (Viscusi, 1993). The authors emphasize that the return to healthcare spending remains positive for all age groups, except for the elderly, for whom the costs for a year of life gained is $145,000, indicating possible "overspending" in US healthcare in this area. Cutler and Meara (2000) demonstrate considerable cost effectiveness of the investment in LBW infant health by considering both the length and the quality of life.

In our study we compare the cost effectiveness of an expensive intervention to both low-cost interventions in middle-income countries and expensive interventions in the US. We add to the literature by analyzing a setting in which on one hand high-tech care is likely to be underutilized, unlike the US, but on the other hand there are institutional barriers and bottlenecks in other healthcare inputs, resulting on uncertain marginal returns compared to the US. Moreover, while most studies on middle-income and developing countries focus on low-cost care and its returns, and we try to verify whether a high-cost but advanced intervention can demonstrate superior or inferior health outcomes and at what price.

III. Economic Mechanism

The opening of the perinatal center primarily changes "technology", which is an input into each region's health production function. Other inputs such as regular obstetricians and number and condition of patients are likely to be stable in the several years' time before and after the opening (we are able to confirm that for obstetricians, neonatologists and midviwes later on). On one hand, we anticipate that Russia had been on the steep portion of its production function curve, and to some extent technology was underutilized and outdated; thus, adding complex technology could improve health outcomes positively and to a larger extent than in richer countries. At the same time, this positive effect may be counteracted by insitutional barriers and insufficient numbers of qualified doctors able to work at the center, so that the cost of year of life saved actually could be higher than in the US.

The mechanism on a micro level will work through a higher probability of admission to a NICU of infants who can benefit most from such treatment. For example, a prematurely born infant who has a collapsed lung will only be able to survive if given an artificial ventilation in a NICU. We regard a NICU treatment as a summary measure for procedures, such as artificial ventilation, diagnostic ultrasound audiological screening, and operations on the heart. Thus, once a perinatal center is open, the probability of an infant at risk (early term birth and/or low birth weight) of accessing a NICU increases. We expect early mortality (0-6 days, 0-28 days, perinatal mortality level) to decrease more than mortality in the other categories, as the group of infants who usually die in the first week survives only through admission into a NICU.

Conversely, the occurrence of deaths in older ages (one month and more) is not expected to change with the presence of NICU, since older infants usually are not admitted there. Thus, such a variable can be used as a placebo test. We expect that infant mortality will decrease overall in a treatment region because the highest risk group will be selected into the NICU and will survive. However, only a decrease in overall (total) infant mortality will show the true effectiveness of the technology, as the survival of the at-risk group on average would exceed one year (as opposed to improved neonatal survival at the expense of increased post-neonatal mortality).

IV. Variables

We run regressions with six categories of mortality rates as outcome variables for our first specification: infant, neonatal, early neonatal and post neonatal mortality, perinatal losses, and stillbirths. Our data are region-level and constitute a 7-year panel (2007-2013) of all (83) Russian oblasts. Births are coded by the address of parents in most cases,whereas deaths are more likely to be reported by the hospital at its own address, so if any mothers choose to go to perinatal centers outside their regions of residence, this may lead to a downward bias through also improving the recorded outcomes in the control groups. However, traveling to the regional capitals with perinatal centers is costly (most regional capitals are located at the center of the region[7]), and there are institutional barriers to giving birth outside one's home. According to the expert opinion of the Chief Neonatologist of Russia, D. N. Degtyarev,[8] although it is legal, it is administrationally costly for a doctor in one region to direct a patient to a hospital in another, which is why doctors are deliberately unlikely to identify sufficient medical conditions for re-directing. So, even if it were true that some mothers give birth outside the region they reside, the number of such mothers is likely to be small. In order be sure, we test whether the number of births changes in the region itself and the neighboring regions after the opening of the perinatal center and add an interaction term for centers close to borders.

We also use additional variables, such as infants born extremely prematurely (22-27 weeks) for 2010 and 2011 and shares of births by weight for years 2010-2012 (published in the Ministry of Health Statistics *Rodovspomozhenie*), maternal mortality and health, using data such as complications after Cesarean operations and post-labor infection (also published in *Rodovspomozhenie*). As is discussed below, these detailed characteristics prove useful in eliminating suspitions as to the possibility of greater undercounting in treated regions.

We collect the first set of outcome variables for 2007-2013 for each oblast from the Central Research Institute for Organization and Informatization of Healthcare, by reaching out to the institute and requesting the access to restricted data. Control variables related to healthcare directly, such as obstetrics beds provision, the number of obstetric and gynecology doctors per woman, and the percent of normal births, are collected from *Rodovspomozhenie.* Local economic and transportation variables, such as income per capita [9] urban and rural population are collected from Rosstat's publication *Regioni Rossii* (2007-2014). To our knowledge, few if any other upper middle income countries have comparable publicly available data.

All variables are summarized by treatment group in Tables A20-A21 and for the overall sample across all years A22 in the Appendix. There are no significant differences in most variables across two groups of interest: treated and to-be-treated. A few exceptions include treated group being more urbanised, and its income per capita being slightly lower, both of which we control for.

V. Methodology

A. Baseline Model

We use a difference in difference (DD) model to estimate the effect of introducing the perinatal centers. The 7-year panel of 83 regions allows us to measure the Average Treatment Effect (ATE); i.e. by how much mortality changes on average if the perinatal center is introduced in any of the regions. Accounting for fixed differences between the treatment

[7]Exceptions are Tomsk, Tyumen, Cheboksary, Ryazan and Gorno-Altaisk

[8]Dmitry Nikolaevich Degtyarev, e-mail message to the author (Nigmatulina), June 19, 2014

[9]Chechen Republic reported missing income per capita in 2007-2009, the three values were replaced by the value in 2010. All regression results are robust to exclusion of the region from the sample

and control groups (with oblast dummies) and capturing the unobserved factors that cause changes in the health outcome even in the absence of a policy change (adding time variant controls and year dummies), we thus measure ATE with a DD approach. The coefficient of interest multiplies the binary variable that is equal to one whenever a center is open in that year and that region.

We account for each oblast's time invariant (at least for 7 years) characteristics, such as baseline wealth, population, geography, ecology and transportation network and the level of healthcare quality, which can affect the underlying level of mortality in each region. By adding a full set of region dummies we remove the above characteristics, including all fixed selection criteria for treatment, such as presence of the medical university and minimum population requirement for the regional capital.[10]

We account for possible serial correlation in the error term with one of the methods that Bertrand and Mullainathan (2004) propose for a large number of states by clustering at the oblast level. This reduces the significance of our coefficients in a preferred specification from 0.05% to 0.1%, indicating that errors are indeed likely to be positively correlated within oblasts.

We should also be aware of that by using a DD estimator with aggregate data we ignore the true sampling variability of mortality in the control oblasts, so the estimated variance could still be too small (Besley and Case, 2000). This problem can only be solved with more detailed data, which we lack at this point.

Our primary regression is as follows:

$$M_{r,t} = \beta_0 + \beta_1 P_{r,t} + \beta_2 Z_{rt} + \lambda_t + \gamma_r + \varepsilon_{r,t} \tag{1}$$

Infant mortality $M_{r,t}$ at time t in region r is affected by the presence of a perinatal center, P_{rt}. Specifically, P_{rt} is the dummy indicating the presence of one of the 24 centers at a particular region in a year t. If the center opens in the beginning of the year, the binary variable takes the value 1 starting from that year; if the center opens in the end of the year, which is usually the case, the value of 1 is only assigned starting the following year, so the treatment is correctly aligned with mortality calculated at the end of each year. In this way, one center opened in 2009 (in Omsk), three centers became effective in 2010, 11 centers started in 2011 and another 9 opened in early 2012. λ_t and γ_r are time and oblast dummy variables. Z_{rt} includes the set of additional region-year factors, such as non-infrastructure healthcare spending in a region, a measure of regional prosperity (income

[10]According to the unpublished presentation by E. N. Baybarina (currently a department head in the Russian Ministry of Health) an oblast is to be selected based on following criteria. If the center is to be built from scratch: 1) shortage of neonatal emergency beds (less than 2 in a 200-300 km radius); 2) existence of a higher medical institution with a Pediatric Department, and 3) readiness of the region to co-finance. If the center is being renovated, selection was awarded to hospitals in which 1) the neonatal emergency room was designed to contain no less than 9 -12 beds 2) the center was planned for being built in cities with no less than 300 000 people 3) there exists a shortage of a neonatal emergency beds, and specifically less than 2 per 1000 births in the radius 200-300 km, and 4) existence of a university-level medical school (Dmitry Nikolayevich Degtyarev, Chief Neonatologist of Russia, email message to author, April 16, 2014). Moreover, D. M. Degtyarev, a member of the selection committee for the regions with the perinatal center, has pointed out in the email that political factors also played a role in the selection.

per capita) and a measure of social distress (recorded cases of alcoholism per capita). Our original list of controls was longer and included measures of social distress such as proportion of the population below the poverty line and alcohol purchases per capita. We instead chose income per capita as it is more informative about the overall wealth in the region and discarded alcohol purchases per capita and used alcoholism occurrence instead, as the former is positively correlated with wealth and thus is a poor control for social distress[11]. Importantly, we should be wary of using variables that are affected by treatment (Wooldridge, 2010, p.910). These include the number of hospital beds and number of neonatologists, because we are unable to condition on these variables being constant and have an unbiased estimator of the effect of treatment. We explore an alternative way of isolating these possible co-moving imputs into healthcare production function in section VI.B. Table A2 demonstrates how our coefficient of interest changes when we sequentially add various fixed effects and controls. We further find that the coefficient β_1 on the key outcome variable, 0-6 year mortality, is robust to the inclusion of the oblast-specific linear time trend. However, our preferred specification excludes a time trend, since otherwise we are left with too few degrees of freedom to have power to estimate the effect on other outcome variables.

We also try a specification with one and two period policy *lead* variables included into our set of controls. *lead1* and *lead2* indicate the policy status one and two periods before the opening of the perinatal center in the treated regions, as in Frakes (2013) and Acemoglu and Finkelstein (2008). We use them to demonstrate that the opening of the center is not associated with some other socio-economic programs in the area that could have been improving health outcomes before the center was introduced. If the coefficients on these variables are positive and significant and coefficients on the perinatal center dummy change value, we should be worried about the true impact of a perinatal center. Finally, the estimate on β_0, the intercept measure, signifies the mean of the fixed effects (Wooldridge, 2010, p.309).

The policy variable is restricted to have the same effect every year (Wooldridge, 2010, p. 151). We also run a sequential model (equation 2), in which we use a set of indicators of one, two and up to five years after opening, indicated by d_i.

$$(2) \qquad M_{r,t} = \beta_0 + \sum_{i=1}^{5} \beta_{1,i} * d_i * Treated_{r,t} + \beta_2 Z_{rt} + \lambda_t + \gamma_r + \psi_t + \varepsilon_{r,t}$$

The DD estimator in equations (1) and (2) is valid and we can estimate the ATE, if the mean changes in the no-program outcome measures are the same for participants and nonparticipants (Heckman, LaLonde and Smith, 1999):

[11]The regression with the alternative controls of social distress is included in the Table A1 of the appendix, in which the coefficients and significance remain almost the same.

$$E(Y_{0t} - Y_{0t'}|D = 1) = E(Y_{0t} - Y_{0t'}|D = 0) \tag{3}$$

If present, bias could be caused by a non-random selection of the treatment and control groups leading to the differential trends in the absence of treatment. We address this issue with the methods below.

B. Test for Pre-Existing Trends and for Other Policies

If the treatment group is developing more rapidly at the time of treatment, it would have a steeper mortality reduction trend and the policy impact may be overestimated. As the financing of a center is done via a matching grant with both federal and local funds, the average of 20% from local funds requirement to co-finance the investment increases the chances of a grant to be awarded to richer areas. Therefore, a wealthier oblast with a larger local budget might have more to spend on other infrastructure and amenities around the center, such as roads and doctor's salaries and benefits, which may improve mortality more even in the absence of treatment. In short, the treated oblasts might get the center because they can make it work. This would make condition in equation (3) fail and bias the estimate of the policy effect away from zero, though the direction is unclear. Better administration could lead to an upward bias; location in wealthier regions that already have relatively good facilities could have the reverse effect.

Another source of potential selection bias is the possibility that federal government gave preference to locations in the greatest *need* of a center, *i.e.*, high congestion in obstetrics units, long queues, or old facilities. Thus, the marginal returns to a center would be higher on average than in the control oblasts, working in addition via expansion of basic facilities and not just improving the technology input.

A formal method to test whether the mortality trends in the absence of policy would have been the same in the treatment and control group is to allow the to-be-treated regions to evolve along a different time trend before the policy. In other words, this test is to regress the mortality variables on overall time trend plus a timetrend to be interacted with the "to-be-treated" dummy in the pre-treatment period 2007-2009. The results in the appendix A7 demonstrate that the treatment group does not reveal any statistically significant difference in the trend from the control in the years prior to treatment for our variables of interest.[12] Stillbirths and one month - one year mortality decline slower on average in treated than in untreated regions, pointing out at that the to-be-treated regions are actually doing worse in some dimensions, but importantly, not in the dimensions we are interested in. Moreover, we run the same baseline regression (1) on pre 2012 and pre 2011 samples with two and three-year leads, respectively, once again as a version of testing for pre-treatment differences in the two groups. The results show no significant effect of this "placebo" policy and are reported in the Appendix (Table A5 and Table A6).

[12]In this estimation we exclude Omsk, as it was treated in 2009, and we need at least 3 periods to test for differential trends.

The risk of endogenous treatment might still not be showing up in the pre-trends: *good oblast effect* may not be internalized in observed mortality *unless* the oblast is treated. However, selected oblasts could be responding better to treatment and that could be the very reason they were selected. In this case it is imossible to estimate an ATE, since the selection variable is not independent or conditionally independent of the unobserved random variable that causes the heterogeneity in the response to treatment (Wooldridge, 2010), p.22.

However, we address the possible selection biases outlined above, when we run our baseline model on a subsample of the regions (54) that are treated plus the regions that are selected for treatment in 2013-2017. In this case, our control group is more likely to both satisfy the DD identification condition by being more similar to the treatment group in terms of all observed criteria for selection and the unobserved "need" and "ability" of the region to maintain a high-tech centre. Both groups are likely to respond to treatment more similarly. We acknowledge, however, that the issue of which oblasts get treated first and what get treated last still stands, but concerns of unobserved differences and possible bias that may be caused by them are much milder.[13] We thus use this specification as our preferred model, as it is the most conservative one possible given the capacity of our data. We also apply all diagnostic tests above to this subsample of 54 regions and they all still hold.

We additionally test for the possibility that mothers are crossing regional borders to be treated in the center, which can cause contamination of control group, and find no evidence of such occurrence at a noticeable scale. In A15 we see that the births neither change significantly in the treated regions after treatment, nor do they change in the nighboring regions after treatment. This shows that there is no evidence of mothers giving births in neighboring treated regions and improving the control regions' statistics, thus biasing our effect downwards. We also do not find an effect if we interact a Perinatal dummy with an indicator of being close to the border.

VI. Results

A. Main Findings

Results suggest that the introduction of perinatal centers reduced infant mortality via saving lives soon after birth. Both Table 1 and Table 2 show results of Model (1) on full sample and sample with to-be-treated controls. We prefer the latter sample, Table 2, because we are wary of the fact that there may be a selection on unobservables that could lead to biased estimates. Infant mortality reduces by 0.391 deaths per 1000 live births, or by 3.8% relative to the baseline mortality rate in 2007 (9.11 deaths per 1000 infants). Neonatal mortality (0-28 days) is reduced by 0.401 deaths per 1000 live births, which

[13]Another way to "purge" the potential endogeneity is to use an instrument orthogonal to the error components and that affects mortality only through the increased probability of selection. Ties of the local governor to Kremlin increase the probability of selection, but arguably do not affect infant mortality directly, hence a proxy of *connection to the federal government* can be a candidate for the instrument. We hypothesized that a good proxy could be years of the governor in power as a measure of connection, but failed to get significant first stage.

Table 1—Effect of Perinatal Center Opening on Infant Mortality, OLS

	(1) 0-1 yr Mortality	(2) 0-28 days Mortality	(3) 0-6 days Mortality	(4) Perinatal Losses	(5) Stillbirths	(6) 28-365 days Mortality
Perinatal Center	-0.582***	-0.451**	-0.293**	-0.533**	-0.241	-0.130
	(0.211)	(0.177)	(0.141)	(0.238)	(0.197)	(0.109)
Income per Capita, in 1000 rub	-0.0186	-0.0176	-0.00792	0.0613	0.0694	-0.00103
	(0.122)	(0.0692)	(0.0511)	(0.0756)	(0.0485)	(0.0587)
Alcoholism (per 1000 population)	0.113	0.173	0.0960	0.322	0.233	-0.0600
	(0.528)	(0.378)	(0.303)	(0.518)	(0.292)	(0.212)
Healthcare Financing, in 1000 rub	0.0419	0.0350	0.00993	0.0554	0.0452	0.00692
	(0.0259)	(0.0220)	(0.0162)	(0.0380)	(0.0338)	(0.0281)
Percent of Urban Population	-0.0418	-0.0675	-0.104	-0.0952	0.00895	0.0257
	(0.1000)	(0.0887)	(0.0691)	(0.0745)	(0.0672)	(0.0607)
Observations	581	581	581	581	581	581
R^2	0.276	0.286	0.249	0.417	0.407	0.127
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No

Standard errors in parentheses
Errors clustered at oblast level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

constitutes a 6.9% average reduction from the baseline rate of 5.5 deaths per 1000 births; mortality in 0-6 days after birth declines by 0.287 deaths per 1000 live births (or 7.3% on average from 3.750 deaths per 1000 births) due to a perinatal center introduction. These numbers suggest that 8-9 fewer infants die in the mean oblast with 23,300 births each year. As expected, the proportional effect on earlier mortality is larger. We see the smallest, but still significant effect of a perinatal center's presence on total infant mortality. As for Table 1, we find that the magnitude of the coefficient on the two early mortality rates is almost the same as in a more conservative model, but the coefficient on infant mortality doubles. This shows that the declining trend for infant mortality in treated regions compared to any other region is likely steeper than that compared to regions that will received treatment in the next stage of the project.

The stillbirths rate declines insignificantly. Reporting rules imposing a more thorough accounting of stillbirths can explain this pattern. With vast shifts in life birth/late abortion criteria, stillbirths are likely to have increased in many regions to offset a decline in the possibility of using late abortions as means of undercounting, and this may have happened regardless of the presence of the perinatal center.

Interestingly, postneonatal mortality does not change at significant levels. We know that

Table 2—Specification with To-Be-Treated Control Group

	(1) 0-1 yr Mortality	(2) 0-28 days Mortality	(3) 0-6 days Mortality	(4) Perinatal Losses	(5) Stillbirths	(6) 28-365 days Mortality
Perinatal Center	-0.391*	-0.401**	-0.287*	-0.429	-0.140	0.0103
	(0.198)	(0.185)	(0.157)	(0.281)	(0.209)	(0.0929)
Income per Capita, in 1000 rub	-0.000581	-0.00891	0.0205	0.0421	0.0249	0.00833
	(0.0615)	(0.0545)	(0.0562)	(0.0839)	(0.0543)	(0.0279)
Alcoholism (per 1000 population)	-0.260	0.0140	-0.000911	-0.182	-0.181	-0.274
	(0.518)	(0.409)	(0.380)	(0.558)	(0.296)	(0.202)
Healthcare Financing, in 1000 rub	-0.0185	-0.000792	-0.000367	0.0116	0.0108	-0.0177
	(0.0379)	(0.0219)	(0.0165)	(0.0287)	(0.0218)	(0.0209)
Percent of Urban Population	-0.00353	0.0410	-0.0237	-0.117	-0.0903	-0.0445
	(0.100)	(0.115)	(0.0826)	(0.113)	(0.102)	(0.0501)
Observations	378	378	378	378	378	378
R^2	0.443	0.373	0.318	0.449	0.434	0.303
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No

Standard errors in parentheses
Errors clustered at oblast level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

the risk of death for LBW and prematurely-born infants is highest in the first week and month of life and it varies highly with the availability of technology. For infants with average weight and gestation the risk of death is more uniformly distributed throughout the first year of life[14] and more likely to vary due to a number of different inputs, such as good care, clean environment and timely doctor's diagnoses. We thus can consider postneonatal category of mortality effectively as a placebo group that less depends on available technology. We are more confident that it is the change in access to equipment in the healthcare production function that is having effect, as we see that only the early mortality groups are affected. This further confirms that our results are not driven by changes that improve health outcomes more generally, other than the improved access to technology.

Table 3 represents a sequential effect of the perinatal center. These results are reliable only for the first three years, since no other treated region except Omsk opened enough years ago for us to have outcomes four and five years after opening. Even for three years after opening we are considering just four treated regions, so some loss of power is expected.

[14]Dmitry Nikolaevich Degtyarev, telephone conversation with the author, Dzhamilya Nigmatulina, May, 2015

Table 3—Sequential Effect of Perinatal Center Opening on Mortality, OLS

	(1) 0-1 yr Mortality	(2) 0-28 days Mortality	(3) 0-6 days Mortality	(4) Perinatal Losses	(5) Stillbirths	(6) 28-365 days Mortality
Year 1 after opening	-0.240	-0.388**	-0.277**	-0.446**	-0.159	0.148
	(0.216)	(0.184)	(0.132)	(0.193)	(0.146)	(0.122)
Year 2 after opening	-0.540*	-0.464*	-0.391*	-0.457	-0.0713	-0.0753
	(0.273)	(0.241)	(0.202)	(0.375)	(0.281)	(0.132)
Year 3 after opening	-0.525*	-0.347	-0.151	-0.366	-0.218	-0.178
	(0.291)	(0.273)	(0.255)	(0.569)	(0.463)	(0.208)
Year 4 after opening	0.0975	0.329	0.586*	0.367	-0.213	-0.231
	(0.274)	(0.252)	(0.326)	(0.695)	(0.432)	(0.181)
Year 5 after opening	-0.287	0.246	0.319	1.301*	0.920**	-0.533***
	(0.288)	(0.292)	(0.308)	(0.661)	(0.433)	(0.184)
Observations	378	378	378	378	378	378
R^2	0.447	0.378	0.330	0.453	0.437	0.313
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

Errors clustered at oblast level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The effect on all three mortality groups of interest (0-6, 0-28 days and 0-1 year mortality) is larger in the second year after opening, as anticipated, since it takes time for the doctors in the center to work out the best practices and get used to the new building and equipment. We witness this result also possibly due to some centers opening later in spring, while the treatment dummy assigned as one for that first year, underestimating the full effect during the year of a center's opening. Three years after opening the effect decreases for all three mortality reates of interest, but more years need to pass before we observe a sufficient number of regions to draw conclusions.

The reduction in all groups of mortality is comparable to the reduction of neonatal mortality in Argentina from improved water facilities of 0.226 from the mean of 2.3 deaths per 1000 live births, which is 11% (Galiani, Gertler and Schargrodsky (2005)), but significantly smaller than those from randomized policies in India and Tanzania (which is easily explained by diminishing marginal returns of mortality being relatively lower in Russia than in Tanzania). Hovever, the US evidence from admission to NICU due to marginally smaller weight enabling an infant meet the admission criteria reduces 0-7 day mortality by 16%, 0-28 day mortality by 23% and one year mortality by 17%, which is higher than what we find in Russia. Finally, Nizalova and Vyshnya (2010) also demostrate a much higher savings of 2.1 lives per 1000 births, vs. 0.391 lives per 1000 births in our study.

B. Additional Considerations

Opening of a center can cause other processes to take place that also indirectly affect mortality in some cases. One such process is diversion of resources from other facilities or their closure. Another change is new centers inviting doctors from other regions to fill in new places. Such processes playing out at the same time as treatment can reduce or increase the effect attributed to the center. Further, there could be differences in the influence of the new center on mortality depending on whether the hospital was built from scratch or the new facility was annexed to the existing hospital, meaning that the institution had already existed. Finally, the change in mortality could be smaller if advanced maternity facilities already existed in a given region, so mothers have had some access to high-tech care already.

First, we test whether the effect of perinatal centers differs when facilities for complicated deliveries already existed in the region before (even if not as advanced), as opposed to the effect from just introducing the complicated delivery care for the first time. We thus add an interaction term $\beta_2 P_{r,t} * Exist$ to our main specification (4), where $Exist_{rt}$ is an indicator for whether the complicated delivery care was available in the region before the new hospital opened. In the resulting Table A8, we see no difference in responses to treatment for 0-6, 0-28 days and 0-1 year mortality. However, there is a significant reduction of stillbirths and of perinatal mortality. This is intuitive, as the difficulty to perform proper and timely diagnostics in simple maternity hospitals affects the likelihood of fetuses to have been stillborn, and there is a significant improvement once an advanced facility opens.

$$M_{r,t} = \beta_0 + \beta_1 P_{r,t} + \beta_1 + \beta_2 P_{r,t} * Exist_{rt} + \phi Z_{rt} + \lambda_t + \gamma_r + \varepsilon_{r,t} \tag{4}$$

We run the same regression as (4) but now interact the treatment with an indicator of whether the hospital has been built from scratch or as part of the existing hospital (Table A9). Except perinatal losses dropping significantly more in regions where the new facility did not belong to a larger existing hospital, there is no significant difference in treatment effect along this dimension. The regions with a large existing hospital that annexed the center tend to be slightly better off than those where it is built as a stand-alone facility, so this additional reduction in perinatal losses stems from the fact that the latter group had some more avertable perinatal losses before treatment.

Regional governments may optimize by detracting resources from other facilities in the region, which, if true, on one hand means that fewer lives are saved, but on the other hand, that these lives are saved at a lower overall cost. We measure the substitution effect with counts of simple maternity units and maternity hospitals, expecting some of these facilities to close after perinatal center opens. Tests for substitution effect are shown in Appendix Tables A10 and A11. In Table A10, we see that the number of maternity hospitals indeed decreased, so we presume that some of the investment was done “at the expense” of old basic hospitals. We explore further by checking if the effect varied by treatment type: the hospital being built from scratch, or within an existing facility. Table A11 shows that maternity hospital counts did not shift significantly differently in the two groups. Is there a difference in the change in mortality if maternity hospital also closed simultaneously? Table A12 shows the effect on our mortality outcomes of the perinatal center interacted with the maternity hospital count. Althought there is not enough obsevations to keep the treatment dummy significant across all mortality outcomes, we see that neonatal mortality does not fall significantly more with higher count of maternity hospitals after treatment. From this, we can conclude that there is no compelling evidence that the substitution effect accompaining the perinatal center openings has a significant impact on mortality.

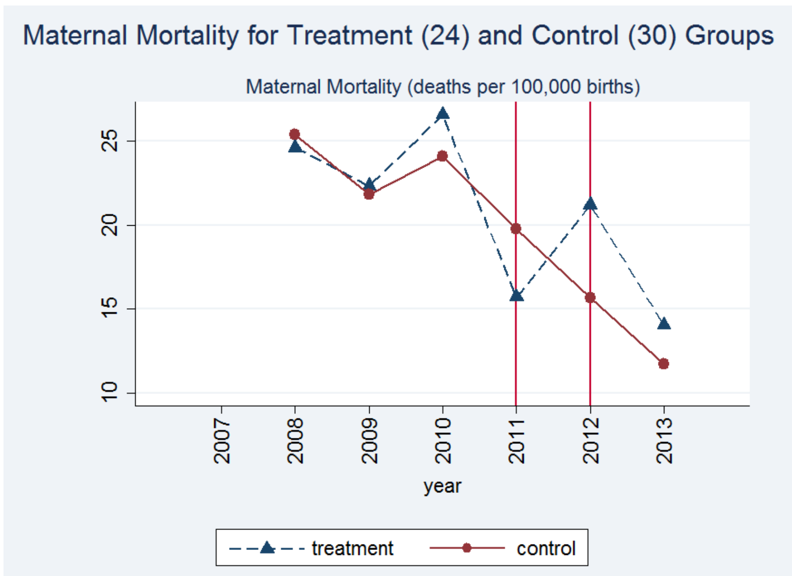
We now explore the changes in Neonatologists, Ob Gyn doctors and midwives (both counts and provision). If these workers are attracted to the treated regions, mortality can drop further, which can blur the effect attributed to the high-tech equipment. However, reassuringly, none of the relevant types of doctors increased significantly in the treated regions after Perinatal Center opening, although the coefficients are positive for midwives and neonatologsts, hinting at some small increases in their counts. To explore this fact, we interact the change in neonatologists in the first year of treatment with the Perinatal Center dummy (Table A13). This result, interestingly, shows that the larger is the increase in Neonatologists in the first year of treatment, the smaller is the reduction in mortality. More variation is necessary to derive firmer conclusions, but it seems that the arriving neonatologists (and it is most plausible they go to work at the new center) need to acquire skills with the new equipment: the transition period thus may avert fewer deaths than the treatment in places where the specialists are locals.

Finally, there is one remaining concern: the out of pocket payments prevalent in Russia. It can be that richer (and thus maybe healthier) mothers are more likely to get themselves into the NICU hospital and get treated, so this can overestimate the treatment effect. If this effect is important, it should lead to improvements in urban (richer) birth outcomes, but not rural (poorer) birth outcomes. We only could find the disaggregated data of infant mortality by urban and rural areas and for a subset of regions; we analyze this data in Table A14. We test run the estimation on both samples, the full control group (78 regions in total) and the preferred sample of controls (51 regions). Surprisingly, in the preferred sample the rural populations’ mortality dereases significatly more and in the full sample the opposite is true. Since in the first case we are comparing more similar regions, it is likely that these results are true and that re-routing of births from remote areas does, indeed, take place.

C. Maternal mortality and morbidity

Not just limiting our analysis to the birth outcomes, we attempt to measure the returns to infrastructure by the level of complications, and mortality for the mother. Maternal adverse outcomes, including both deaths and complications are estimated using a familiar DD estimator, $\hat{\beta}_1$. The results are not straightforward, since it appears that maternal mortality increased with the introduction of the perinatal center. Furthermore, from the results in the appendix (Tables A18 and A19) there is no notable improvement in terms of the complications for the mother and even worsening of one complication (diabetes).

Figure 2. Trends for Perinatal Mortality, Stillbirths and Other Variables



There may be several explanations for these anomalous findings. First, mortality of mothers is a relatively rare case: in all Russia 291 mothers died in childbirth in 2011. This means that even one more death can lead to a large percentage increase in the maternal mortality rate per 100,000 births. Moreover, both for complications and mortality, we must remember that some proportion of the unaccounted adverse cases in 2012 include late abortions and miscarriages. If this addition of unfavorable outcomes to birth statistics happens to be larger for treatment regions, more mothers' deaths would appear to be caused by treatment (but in reality are accidental). As for complications, they could also indicate a trade-off in the decision to carry a risky pregnancy to term (instead of aborting): once a perinatal center is available, more older mothers might decide to do carry to term, being more confident that their delivery can be addressed with modern medical techniques. As a result, more complications can arise.

D. Measurement error

We now revisit the measurement error issue. It is both a curse and a blessing that perinatal centers' opening have coincided with the statistics criteria change. On one hand, the shifts in all mortality indicators in 2012 offer a clue as to the degree of underreporting in each region in the past as outlined in Appendix section A.A2. On the other hand, it is possible that a new type of underreporting started taking place due to the new rules, just around the new threshold of 500 grams birth weight and 22 weeks of gestation, which is impossible to measure. The issue of undercounting is only a threat to the validity if it is systematically different in treated regions. It is reasonable that local authorities would encourage hospitals to demonstrate that the federal investment of about 2 billion rb per center was not in vain. At the same time, better statistical standards and more careful observation might be enforced inside the center itself, improving the reporting overall. In this case the bias is towards zero.

The occurrence of infants of a particular mass range is generally determined by biological characteristics of the mother. Hospitals themselves cannot immediately influence the distribution of infant and fetus weight. However, the way accounting is done in the hospital can affect the way these occurrences *are reported*. Before 2012 and after 2013 a region will be undercounting differently. Before 2012 the category of 1000-1500 g (VLBW) will be smaller relative to 500-999g (ELBW) and bunching will occur at 500-999g, because this "bin" would not have gone into the official statistics. In contrast, after 2012 the undercounting will happen around the new threshhold of 500g (arguably to a smaller degree, since there are fewer marginal cases at 500g). After 2012 the 1000-1500 category is expected to return to "normal", whereas the ELBW category would experience a proportional decline (both because new undercounting could potentially take place at 500g threshold and because previosly marginal cases at 1000g would now be assigned a correct weight). The analogous logic applies to late abortions (22-28 weeks of gestation before 2012). Keeping the above in mind, we would like to determine whether the degree of undercounting is ever affected by the introduction of the center. We use three variables that can signal the undercounting and first test this for a subsample of perinatal center introductions before 2012. Equations 6 and 7 test whether the late abortions ($LateAbort_{r,t}$) or the share of 1000-1500g infants ($VLBW_{r,t}$) were affected by the introduction of the center in 2011. All regions that did not experience a change in perinatal center status in 2011 become part of the control group.

$$LateAbort_{r,t} = \beta_0 + \beta_1 d2011 + \beta_2 Treat_{cohort_{11}} + \beta_3 Treat_{cohort_{11}} d2011 + \beta_4 Z_{r,t} + \varepsilon_{r,t} \tag{5}$$

$$VLBW_{r,t} = \beta_0 + \beta_1 d2011 + \beta_2 Treat_{cohort_{11}} + \beta_3 Treat_{cohort_{11}} d2011 + \beta_4 Z_{r,t} + \varepsilon_{r,t} \tag{6}$$

$Treat_{cohort_{11}}$ stands for all the 11 centers that opened in early 2011 (or late 2010) and d2011 is the dummy for year 2011. The regression is run with all the controls and oblast fixed effects from the baseline model ($Z_{r,t}$). We find neither differential change of late abortions nor of the VLBW infants' share, and the results are reported in the Appendix (Table A17).

We then investigate changes in Extremely Low Birth Weight (ELBW) proportion for years 2010 and 2012 (the only two years we were able to obtain) and run an analogous specification for the cohort of nine regions that opened in 2012 ($Treat_{cohort_{12}}$), compared to all other regions as controls.

$$\begin{aligned} ELBW_{r,t} =& \gamma_0 + \gamma_1 d2012 + \gamma_2 Treat_{cohort_{12}} + \gamma_3 Treat_{cohort_{12}} d2012 \\ &+ \gamma_4 Z_{r,t} + \nu_{r,t} \end{aligned} \tag{7}$$

Assuming a normal true distribution of birth weights (Starodubov and Sukhanova, 2013), the share of 1000-1500 g births would increase and the share of 500-1000 g births would decrease, because bunching no longer happens at 1000g. Surprisingly, in Table A16, columns 1 and 3 illustrate that although 1000-1500g births increased as expected, the proportion of 500-750g births has increased to some extent as well. This suggests that undercounting in Russia had been even more severe prior to 2012, and many cases below 1000g were not accounted for even in the unofficial hospital statistics before 2012. The change in the policy has induced more accurate accounting of the lightest infants. In any case, the shares of birth weights for any birth weight group are not differentially affected by perinatal center opening.

E. Cost-benefit analysis

Table 4—Cost-Benefit Analysis of a Perinatal Center in an Average Region

Benefits	
Lives Saved	
Average births in an oblast in 2013	23,292
Average lives saved (average births times 0.391 reduction in infant mortality)	9.11
Value of Life	
GDP , mln rb	71,406,400
Working population, count	85,161,578
GDP per worker, rb	838,481
Lifetime work duration (ages 16-59), years	43
Value of Life (multiplying work duration by GDP per worker), mln rb	36
Present Value Benefits (over 40 years' lifetime of a hospital), mln rb	10,286
Costs	
Operational	
Average Monthly Wage of Doctors and Nurses, rb	29,557
Yearly Wages of 600 Workers (conservative value), mln rb	213
Yearly Wages with Additional 5.4% OMS (workers' insurance), mln rb	224
Maintenance (30% on average from yearly wages), mln rb	320
Present Value of Future Operational Costs, mln rb	10,038
Investment	
Total Capital Investment per Center, mln rb	2,064
Present Value Total Costs, mln rb	12,102
Interest rate (Bank of Russia avg interest rate to non-finance organizations in roubles for more than 3 yrs)	8.25%
Discount Rate Adjusted for Average Inflation of 7%	1.25%
Present Value Factor for Future Income Flow of 40 Years	0.04
Net Present Value, mln rb	-1,816
Percent Return	-15,00%

Considering large monetary investments into the perinatal centers without an a priori obvious return, a cost-benefit analysis is imperative for policy evaluation and comparison with other interventions (for instance, with the return on Mother and Infant Project in Ukraine (Nizalova and Vyshnya, 2010)). We do two types of evaluations: a rate of return

Table 5—Cost Comparisons of Different Health Interventions

Incremental cost per QALY	As quoted	In 2014 dollars
Our estimate, high-tech neonatal care, 2014 PPP $	44,900	44,900
Cutler and Meara (2000), Neonatal care (US, 1990), $	3,726	6,065
Cutler and Meara (2000), Prenatal care (US, 1990), $	(4,214)*	(6,859)*
Cutler and Meara (2000), Influenza vaccinations <3 years (US, 1990), $	1,745	2,840
Cutler and Meara (2000), Coronary artery bypass (US, 1990), $	33,600-48,300	54,700-78,700
Cutler and Meara (2000), Severe hypertension treatment (US, 1990), $	17,000	27,700
Cutler and Meara (2000), Pap Smear every 3 years for ages 20-74, $	17,000	27,700
Mangham-Jefferies et al. (2014), Promoting hospital-based breast-feeding (Honduras, 1993), $	164 (per DALY** averted)	249
Mangham-Jefferies et al. (2014), Outreach obstetrics units, referral assistance, training birth assistants (The Gambia, 1991), $	148-620 (per LY***)	153-640
Cost per life saved		
Our estimate, high-tech neonatal care, 2014 PPP $	2,619,000	2,619,000
Mangham-Jefferies et al. (2014), Promoting hospital-based breast-feeding (Honduras, 1993), $	6,894	7,120
Mangham-Jefferies et al. (2014), Outreach obstetrics units, referral assistance, training birth assistants (The Gambia, 1991), $	1,380-6,414	1,400-6,625
Mangham-Jefferies et al. (2014), Tetanus Toxoid immunization (Indonesia, 1985), $	1,564	1,615
Nizalova and Vishnya (2010) Mother and Infant Project (Ukraine, 2005), $	10,657	12,592
Almond et al. (2010), Neonatal intensive care (US, 1983-2002), $	527,083-615,270	566,000-660,650

Notes: * Cost savings, **Disability Adjusted Life Year, *** Life Year

over the lifetime of a hospital (40 years[15]), and an estimation of a cost per life saved or per incremental year of life in order to compare our finding to other studies. For either measure we use interest rate, and estimate of operational costs and capital costs. For capital costs we use an average stated capital investment of the perinatal center (2.064 bln rb or \$103.2 mln in 2014 PPP USD). Operational cost is derived from the fact that most centers range between 130 -190 beds, and the number of people employed range between 600 (Kurgan) and 900 (Tomsk), but employee information was only available for a few hospitals. Taking 600 as a lower bound, and information on average wages of healthcare workers from Rosstat, we assume that doctors, nurses and junior nurses work in the center in equal proportions and find that a hospital on average needs to pay around 213 million rb in wages yearly. Adding a 5.4% required insurance and 30% typically allocated maintenance cost on top of the wages[16] we assume operational cost to be 320 million rb, or (16 million 2014 USD in PPP). We convert the yearly costs and benefits to present value terms we utilize the Central Bank of Russia's discount rate of 8.25% for 2012 (*stavka refinansirovaniya*) Adjusting the future cash flows by Russia's average inflation of 7%, the real interest rate becomes 1.25%.

[15]Expert opinion of Guzel Ernstovna Ulumbekova, email message to the author (Nigmatulina), 04 Oct, 2015
[16]ibid

Table 6—Sensitivity Analysis of Returns to a Perinatal Center With Regard to the Yearly Number of Births and Different VSL

		Number of Births in a Region										
		1 000	10 000	15 000	20 000	30 000	40 000	50 000	70 000	90 000	100 000	130 000
VSL, mln rb	20	-98%	-80%	-70%	-60%	-39%	-19%	1%	42%	82%	102%	163%
	25	-97%	-75%	-62%	-49%	-24%	1%	27%	77%	128%	153%	229%
	30	-97%	-70%	-54%	-39%	-9%	21%	52%	113%	173%	204%	295%
	35	-96%	-65%	-47%	-29%	6%	42%	77%	148%	219%	254%	361%
	40	-96%	-60%	-39%	-19%	21%	62%	102%	183%	264%	305%	426%
	45	-95%	-54%	-32%	-9%	37%	82%	128%	219%	310%	355%	492%
	50	-95%	-49%	-24%	1%	52%	102%	153%	254%	355%	406%	558%
	55	-94%	-44%	-17%	11%	67%	123%	178%	290%	401%	457%	624%
	60	-94%	-39%	-9%	21%	82%	143%	204%	325%	447%	507%	689%
	65	-93%	-34%	-1%	32%	97%	163%	229%	361%	492%	558%	755%
	70	-93%	-29%	6%	42%	113%	183%	254%	396%	538%	608%	821%
	75	-92%	-24%	14%	52%	128%	204%	280%	431%	583%	659%	887%
	80	-92%	-19%	21%	62%	143%	224%	305%	467%	629%	710%	953%

In order to monetize the lives saved by a new perinatal center, we can turn to the expert estimates of Value of Statistical Life (VSL) in Russia. Guriyev (2011) suggests the VSL to be in the 60-135 mln rb ($2-4.5 mln) range. Bykov (2007) offers a slightly smaller, but comparable estimate, 50 mln rb, or $1.6 mln in 2014 dollars. We also estimate our own VSL to the government by dividing the GDP by working population and multiplying by 43 years of expected working life to get 36 mln rb. We recognize that the resulting returns to investment are sensitive to the VSL chosen, which is why we provide sensitivity analysis (Table 6). We finally multiply the VSL with the newborn lives saved per year in a region and subtract the estimated average annual cost for a perinatal center.

Using our own VSL we find that an average perinatal center has a return to investment of negative 15% in a region with 23,292 yearly births (the average from 2013). In order to get a very small positive return of 1%, VSL needs to reach 50 mln in an average region or the region needs to have more than 30,000 births. Similarly, in Table 7 we see that keeping the VSL at 36 million rb, and for an average region with 30000 births, the return to a perinatal center varies from 1% (for 3.5% discount rate) to 9% (for 1.25% discount rate). We also assume that infants surviving past 1 year of life have an average life expectancy and quality. However, it is important to note that estimating these benefits is done without considering any health benefits to the mother and better morbidity outcomes for infants who would not have died in the absence of treatment.

Table 7—Sensitivity Analysis of Returns to a Perinatal Center With Regards to the Yearly Number of Births and Different Discount Rates

		Number of Births in a Region										
		1 000	10 000	15 000	20 000	30 000	40 000	50 000	70 000	90 000	100 000	130 000
Discount Rate	1.25%	-96%	-64%	-45%	-27%	9%	46%	82%	155%	228%	265%	374%
	1.50%	-96%	-64%	-46%	-28%	9%	45%	81%	153%	226%	262%	371%
	1.75%	-96%	-64%	-46%	-28%	8%	44%	80%	151%	223%	259%	367%
	2.00%	-96%	-64%	-47%	-29%	7%	42%	78%	149%	220%	256%	363%
	2.25%	-96%	-65%	-47%	-29%	6%	41%	77%	147%	218%	253%	359%
	2.50%	-96%	-65%	-47%	-30%	5%	40%	75%	145%	215%	250%	355%
	2.75%	-97%	-65%	-48%	-31%	4%	39%	74%	143%	212%	247%	351%
	3.00%	-97%	-66%	-48%	-31%	3%	38%	72%	141%	210%	244%	347%
	3.25%	-97%	-66%	-49%	-32%	2%	36%	71%	139%	207%	241%	343%
	3.50%	-97%	-66%	-49%	-32%	1%	35%	69%	137%	204%	238%	339%
	3.75%	-97%	-67%	-50%	-33%	0%	34%	67%	134%	201%	235%	335%
	4.00%	-97%	-67%	-50%	-34%	0%	33%	66%	132%	199%	232%	332%
	4.25%	-97%	-67%	-51%	-34%	-1%	32%	64%	130%	196%	229%	328%
	4.50%	-97%	-67%	-51%	-35%	-2%	30%	63%	128%	193%	226%	324%
	4.75%	-97%	-68%	-52%	-35%	-3%	29%	61%	126%	191%	223%	320%
	5.00%	-97%	-68%	-52%	-36%	-4%	28%	60%	124%	188%	220%	316%
	5.25%	-97%	-68%	-52%	-37%	-5%	27%	58%	122%	185%	217%	312%
	5.50%	-97%	-69%	-53%	-37%	-6%	26%	57%	120%	183%	214%	308%

Nizalova and Vyshnya (2010) find that the Mother and Infant Project in Ukraine generated 962% return accounting for the lives saved, which is in a much higher range than positive returns in Russia, especially considering a much more conservative use of VSL for Ukraine: if Russian values were used, the return would be even higher). Such evidence points out that there could be other ways to avert deaths in Russia, with a much smaller investment, though the difference also reflects the dire state of healthcare funding in Ukraine.

Estimating the cost per life saved we first find that the perinatal centers altogether save 263 lives per year and have saved approximately 735 lives so far since 2009. To get the first value we multiply all the births in the treated regions in 2013 (when all 24 centers were open) by the reduction in mortality rate attributed to the centers (0.391 deaths per 1000 births from Table 2). As for the latter value, we multiply the births occurring in each region once it is subject to policy in years 2009-2013 with the 0.391 reduction in deaths per 1000 births attributed to the centers. Then we use an average investment cost of a perinatal center in a region, annualized over 40 years using annualization formula[17] (65,886,000 rb) plus the yearly perinatal center costs (320,000,000) and divide the total cost by the number of estimated lives saved in each region as in Almond et al. (2010) and average across regions to get the national value. The cost per life saved from our calculations is 52,153,000 rb

[17] $d = P * r/(1-1/(1+r)^T)$ where $P = 2,064,000,000$ is the average cost of building a perinatal center, $r = 0.0125$ is the Bank of Russia interest rate net of inflation, $T = 40$ and is the upper bound of a lifetime of a hospital

(or 1,380,000 in 2014 USD or 2,619,000 in PPP 2014 USD). Regardless of which dollar equivalent we choose[18], the value per live saved is significantly larger than that quoted by Almond et al. (2010): $527,083-$615,270 in 2010. In the Ukranian study the evidence is that 5.63 lives are saved per maternity-year with 60,000 2005 USD cost per maternity per year. This translates into a 2014 USD cost per life saved for Ukranian investment of 12,592 2014 USD, which is around 100 times cheaper than the high-tech investment in Russia.

To be able to compare to a few other studies we calculate the cost per quality-adjusted life year (QALY). Since we do not have any information on quality of life conditional on the weight of the newborn whose life is saved in our hospitals, we use estimations from Cutler and Meara (2000) assuming that all lives saves are those of LBW newborns, and that in Russia in 2014 newborns of a certain weight on average can expect to live a life of comparable quality as in the US in 1990, and have the same longevity *relative* to the Russia's average life expectancy. Knowing the shares of different LBW categories in 2013 for Russia we estimate that on average a LBW infant who survived to 1 year will live 58.3 QALY's[19]. In Table 5 we compare our findings with costs for QALY or cost for life saved for various interventions from studies that presented their findings in this comparable way. A number of studies have been made evaluating cost effectiveness of different mother and infant interventions in developing countries (for a detailed review, see Mangham-Jefferies et al. (2014)). We list some of the costs in Table 5 and include estimated return from other studies as well. Our cost per QALY finding stands as one of the highest on this list only surpassed by Coronary arthery bypass.

VII. Conclusion

Investment in high-tech infrastructure reduces infant mortality on a middle-income country, but at a high cost. Building state-of-the-art hospitals in 24 out of 83 regions in Russia reduced infant mortality rate by 3.8% on average (or the rate became lower by 0.0391 percentage points), but each life saved costed the government around 52 million rb (2.6 million 2014 PPP USD), which is higher than most similar investments in the US. This demostrates that bottlenecks such as institutional capacity to build hospitals at lower costs, or lack of other quality inputs into healthcare, remain and restrict the potential effect from the investment. The subject of the study is further relevant, as the federal government plans to build centers in additional 30 regions, and it is important to accurately predict expected mortality reductions from the investment. If the reduction of mortality is expected to be the same as in the current part of the investment, only the large regions with more than 30,000 births a year should expect a positive return, and only if a life is valued at 30 mln rb or more.

At the same time, the regions that built a perinatal center in the last three years did achieve the government-set target rates of early neonatal mortality that declined from 3.66 to 2.9, compared to 3.82 to 3.24 (when the control group is regions "to-be-treated"). The

[18] we believe that PPP 2014 USD is most accurate numeraire for comparison with the US result, because it represents the cost to the government in real terms

[19] We are only considering cases of infants who survived their first year of life for this QALY calculation.

establishment of a perinatal center redues infant mortality by saving babies in the first week and in the first month of their lives. The largest reduction in the rate compared to baseline rate in 2007 is for first week mortality (7.3%). No significant effect is noted for postneonatal mortality and a possible increase in maternal mortality is found. We believe the latter finding is due to the low counts of death outcomes for mothers in Russia, and that this pattern is unrelated to the perinatal center.

We address two major concerns with the validity of the results. First, the propensity of the selected regions (in 2007) to benefit from the center may be higher than that of a usual control region, so the DD estimate might exaggerate the treatment effect. We carefully select the control group and only include regions that are subject to treatment in the seond stage of the policy. We further test for the preexisting differences in the trends for the treatment and control groups. Second, the degree of mortality underreporting could be higher in the treated oblasts, since they have an incentive to demonstrate favorable effects of the federal investment. We rule this concern out with diagnostic regressions on variables that capture underreporting: terminations of pregnancy in 22-27 weeks of gestation and proportion of births by birth weight.

It bears mention that our estimates of benefits are restricted to lives saved directly. To a modest extent, then, the true returns of the perinatal center may be underestimated, since the treatment in the center have very likely improved morbidity rates as well. Unfortunately, we do not have any information on improved morbidity or how to quantify it. In addition, the center should raise the overall obstetrics care quality in the region by interacting with other hospitals, encouraging the dissemination of best practices, and monitoring their performance in the long run. Nevertheless, the investment remains expensive when compared to similar studies in other countries, which also only consider lives saved as their outcome measure.

The commitment of roughly 75 billion rb (3.8 billion 2014 USD in PPP) to creating NICUs, along with still larger operation costs, is a major commitment by the Russian Ministry of Health and has accounted for about 1/3 of the 2013 capital budget of 222.5 billion rb. As cited in Evans and Garthwaite (2012), $1.1 billion was spent in the US for a comparative effectiveness research in the frame of the American Recovery and Reinvestment Act that became law in 2009. Such a detailed research investment may be costly in a country that may lack basic accessibility of care. However, when resources allocated to healthcare are limited, comparing relative returns of major investment, such as Neonatal Intensive Care Units, high-tech cardiac centers, or, increasing the number of beds in a large number of hospitals, is absolutely necessary. Although the evidence is that the money spent on Perinatal Centers' project has yielded some returns, there may exist much higher returns from addressing basic needs of current Russian healthcare system, such as increasing the number and quality of maternity units accessible to those who live far from big centers. Upper middle income countries will be making vast health infrastructure investments in the near future and one should not underestimate the importance of informed choices to achieve higher returns to healthcare.

REFERENCES

Acemoglu, Daron, and Amy Finkelstein. 2008. "Input and Technology Choices in Regulated Industries: Evidence from the Health Care Sector." *Journal of Political Economy*, 116(5): 837–880.

Almond, Douglas, and Joseph J Doyle Jr. 2011. "After Midnight: A Regression Discontinuity Design in Length of Postpartum Hospital Stays." *American Economic Journal: Economic Policy*, 3(3): 1–34.

Almond, Douglas, Joseph J Doyle, Amanda E Kowalski, and Heidi Williams. 2010. "Estimating Marginal Returns to Medical Care: Evidence from At-Risk Newborns." *The Quarterly Journal of Economics*, 125(2): 591.

Anderson, Barbara A, and Brian D Silver. 1986. "Infant Mortality in the Soviet Union: Regional Differences and Measurement Issues." *Population and Development Review*, 12(4): 705–738.

Andreyev, Ye M, and Ye A Kvasha. 2002. "Osobennosti Pokazateley Mladencheskoy Smertnosti v Rossii [Features of infant mortality in Russia]." *Problemy Sotsial'noy Gigiyeny, Zdravookhraneniya i Istorii Meditsiny*, 4: 15–20.

Anthopolos, Rebecca, and Charles M. Becker. 2010. "Global Infant Mortality: Correcting for Undercounting." *World Development*, 38(4): 467–481.

Baicker, Katherine, and Amitabh Chandra. 2004. "Medicare Spending, the Physician Workforce, and Beneficiaries' Quality of Care." *Health Affairs*, W4: 184–197.

Baicker, Katherine, and Amitabh Chandra. 2011. "Aspirin, Angioplasty and Proton Beam Therapy: the Economics of Smarter Health-Care Spending." *Federal Reserve Bank of Kansas City Proceedings*, 197–235.

Bang, Abhay T, Rani A Bang, Sanjay B Baitule, M Hanimi Reddy, and Mahesh D Deshmukh. 1999. "Effect of Home-Based Neonatal Care and Management of Sepsis on Neonatal Mortality: Field Trial in Rural India." *The Lancet*, 354: 1955–1961.

Bertrand, Marianne, Duflo Esther, and Sendhil Mullainathan. 2004. "How Much Should we Trust Differences-in-Differences Estimates?" *Quarterly Journal of Economics*, 119(1): 249–275.

Besley, Timothy, and Anne Case. 2000. "Unnatural Experiments? Estimating the Incidence of Endogenous Policies." *Economic Journal*, 110(467): F672–94.

Bykov, Andrey. 2007. "O Metodologii Otsenki Stoimosti Srednestatisticheskoy Zhizni Cheloveka [On the methodology for assessing the value of a statistical life]." *Strakhovoye Delo*, 3: 10–25.

Cutler, David M, Allison B Rosen, and Sandeep Vijan. 2006. "The Value of Medical Spending in the United States, 1960–2000." *New England Journal of Medicine*, 355(9): 920–927.

Cutler, David M, and Ellen Meara. 2000. "The Technology of Birth: Is It Worth It?" *Frontiers in Health Policy Research*, 3: 33–68.

Cutler, David M, and Mark McClellan. 2001. "Is Technological Change in Medicine Worth It?" *Health Affairs*, 20(5): 11–29.

Cutler, David M, Mark McClellan, Joseph P Newhouse, and Dahlia Remler. 1998. "Are Medical Prices Declining? Evidence from Heart Attack Treatments." *Quarterly Journal of Economics*, 991–1024.

Doyle, Joseph J. 2011. "Returns to Local-Area Healthcare Spending: Evidence From Health Shocks to Patients far from Home." *Amerian Economic Journal: Applied economics*, 3(3): 221–243.

Evans, William N, and Craig Garthwaite. 2012. "Estimating Heterogeneity in the Benefits of Medical Treatment Intensity." *Review of Economics and Statistics*, 94(3): 635–649.

Federation Council of Russia. 2013. "Federal Law N 349-." *http://www.rosminzdrav.ru/documents/8032-federalnyy-zakon-ot-2-dekabrya-2013-g-n-349-fz-o-federalnom-byudzhete-na-2014-god-i-na-planovyy-period-2015-i-2016-godov*, [Online, accessed 26-July-2014].

Finkelstein, Amy, and Robin McKnight. 2008. "What Did Medicare Do? The Initial Impact of Medicare on Mortality and Out of Pocket Medical Spending." *Journal of Public Economics*, 92(7): 1644–1668.

Fisher, Elliott S, David E Wennberg, Thrse A Stukel, Daniel J Gottlieb, F Lee Lucas, and Etoile L Pinder. 2003. "The Implications of Regional Variations in Medicare Spending. Part 2: Health Outcomes and Satisfaction with Care." *Annals of internal medicine*, 138(4): 288–298.

Frakes, Michael. 2013. "The Impact of Medical Liability Standards on Regional Variations in Physician Behavior: Evidence from the Adoption of National-Standard Rules." *American Economic Review*, 103(1): 257–76.

Fuchs, Victor R. 2004. "More Variation in Use of Care, More Flat-of-the Curve Medicine." *Health Affairs*, 23: 104–107.

Galiani, Sebastian, Paul Gertler, and Ernesto Schargrodsky. 2005. "Water for Life: The Impact of the Privatization of Water Services on Child Mortality." *Journal of Political Economy*, 113(1): 83–120.

Gamper-Rabindran, Shanti, Shakeeb Khan, and Christopher Timmins. 2010. "The Impact of Piped Water Provision on Infant Mortality in Brazil: A Quantile Panel Data Approach." *Journal of Development Economics*, 92(2): 188–200.

Gill, Christopher J, Grace Phiri-Mazala, Nicholas G Guerina, Joshua Kasimba, Charity Mulenga, William B MacLeod, Nelson Waitolo, Anna B Knapp, Mark Mirochnick, Arthur Mazimba, et al. 2011. "Effect of Training Traditional Birth Attendants on Neonatal Mortality (Lufwanyama Neonatal Survival Project): Randomised Controlled Study." *BMJ: British Medical Journal*, 342.

Gonzalez, Robert M. 2013. "Underreporting of the Infant Mortality Rate: Evidence and Adjustments for Cuba." *http://ssrn.com/abstract=2442565*.

Goodman, David C, Elliott S Fisher, George A Little, Therese A Stukel, Chiang-hua Chang, and Kenneth S Schoendorf. 2002. "The Relation between the Availability of Neonatal Intensive Care and Neonatal Mortality." *New England Journal of Medicine*, 346(20): 1538–1544.

Grumbach, Kevin. 2002. "Specialists, Technology, and Newborns – Too Much of a Good Thing." *New England Journal of Medicine*, 346(20): 1574–1575. PMID: 12015399.

Guriyev, Sergey. 2011. *Mify Ekonomiki: Zabluzhdeniya i Stereotipy, kotoryye Rasprostranyayut SMI i Politiki [Myths of Economics: Misconceptions and stereotypes that are distributed by the media and politicians].* Moscow:Mann, Ivanov i Ferber.

Heckman, James J, Robert J LaLonde, and Jeffrey A Smith. 1999. "The Economics and Econometrics of Active Labor Market Programs." *Handbook of labor economics*, 3: 1865–2097.

Kvasha, Ye A, and T L Khar'kova. 2012. "Smertnost' Mladentsev v Rossii: Uspekhi i Nereshennyye Problemy [Infant mortality in Russia: Successes and Remaining Challenges]." *Mir Rossii*, 3: 3–40.

Latukhina, Kira. 2013. "Formula Spravedlivosti [A Formula of Justice]." *http://www.rg.ru/2013/04/04/medtsentri-site.html*, [Online, accessed 18-Oct-2014].

Luce, Bryan R, Josephine Mauskopf, Frank A Sloan, Jan Ostermann, and L Clark Paramore. 2006. "The Return on Investment in Health Care: from 1980 to 2000." *Value in Health*, 9(3): 146–156.

Mangham-Jefferies, Lindsay, Catherine Pitt, Simon Cousens, Anne Mills, and Joanna Schellenberg. 2014. "Cost-Effectiveness of Strategies to Improve the Utilization and Provision of Maternal and Newborn Health care in Low-Income and Lower-Middle-Income Countries: a Systematic Review." *BMC pregnancy and childbirth*, 14(1): 243.

Ministry of Healthcare of the Russian Federation. 1992. "Attachment 1 to Executive Order N 318." *http://naturalbirth.ru/pravo/index.php?page=pr318#p1*, [Online, accessed 11-June-2014].

Ministry of Healthcare of the Russian Federation. 2008. "Executive Order N 1833-p." *http://www.szrf.ru/doc.phtml?nb=edition00&issid=2007050000&docid=78*, [Online, accessed 11-June-2014].

Ministry of Healthcare of the Russian Federation. 2013. "Executive Order N 2302-p." *http://www.rg.ru/2013/12/10/perinatal-site-dok.html*, [Online, accessed 11-June-2014].

Muraskas, Jonathan, and Kayhan Parsi. 2008. "The Cost of Saving the Tiniest Lives: NICUs versus Prevention." *Virtual Mentor*, 10(10): 655.

Nizalova, Olena Y, and Maria Vyshnya. 2010. "Evaluation of the Impact of the Mother and Infant Health Project in Ukraine." *Health Economics*, 19(S1): 107–125.

Paneth, Nigel S. 1995. "The Problem of Low Birth Weight." *The Future of Children*, 19–34.

Penina, Olga, France Meslé, and Jacques Vallin. 2011. "Correcting for Under-Estimation of Infant Mortality in Moldova." *Population (English edition)*, 65(3): 499–514.

Regiony Rossi. Social'no-Ekonomicheskie Pokazateli [Regions of Russia. Socio-economic indicators]. 2007, 2008, 2009, 2010, 2011, 2012, 2013. Moscow.

Salomon, LJ, JP Bernard, and Y Ville. 2007. "Estimation of Fetal Weight: Reference Range at 20–36 Weeks' Gestation and Comparison with Actual Birth-Weight Reference Range." *Ultrasound in Obstetrics & Gynecology*, 29(5): 550–555.

Schwarcz, Sandra K, Ling Chin Hsu, Eric Vittinghoff, and Mitchell H Katz. 2000. "Impact of Protease Inhibitors and Other Antiretroviral Treatments on Acquired Immunodeficiency Syndrome Survival in San Francisco, California, 1987–1996." *American Journal of Epidemiology*, 152(2): 178–185.

Starodubov, V I, and L P Sukhanova. 2013. "New Criteria of Birth: Medical and Demographic Results and Organizational Problems in Obstetrics Care." *Menedger Zdravookhraneniya*, 12: 21–29.

Sukhanova, L P. 2011. "Statistika Sluzhby Rodovspomozheniya v Rossii i Regionakh Tsentral'nogo Federal'nogo Okruga [Statistics obstetrics service in Russia and the Central Federal District]." *http://www.healthquality.ru/open/index_con.php?obj=co_library&ac=index&fl_id=573*, [Online, accessed 27-May-2014].

Sukhanova, L P. 2012. "Analysis of Mother and Infant Indicators during the Obstetrics Care Reform in Russia in 2006-2011." *http://www.mednet.ru/images/stories/files/materialy_konferencii_i_seminarov/2010/stat2012/12_Sukhanova.ppt*, [Online, accessed 11-June-2014].

Viscusi, W Kip. 1993. "The Value of Risks to Life and Health." *Journal of Economic Literature*, 31: 1912–1946.

Watson, Tara. 2006. "Public Health Investments and the Infant Mortality Gap: Evidence from Federal Sanitation Interventions on US Indian Reservations." *Journal of Public Economics*, 90(8): 1537–1560.

Wehby, George L, Jeffrey C Murray, Eduardo E Castilla, Jorge S Lopez-Camelo, and Robert L Ohsfeldt. 2009. "Quantile Effects of Prenatal Care Utilization on Birth Weight in Argentina." *Health Economics*, 18(11): 1307–1321.

Williams, Ronald L, and Peter M Chen. 1982. "Identifying the Ssources of the Recent Decline in Perinatal Mortality Rates in California." *Obstetrical & Gynecological Survey*, 37(7): 454–456.

Wooldridge, Jeffrey M. 2010. *Econometric Analysis of Cross Section and Panel Data.* . 2 ed., Cambridge, Massachusetts:MIT Press.

World Health Organization Europe. 2014. "European Health for All Database: Definitions (HFA DB)." *http://data.euro.who.int/hfadb/definitions/def.php?w=1366&h=768*, [Online, accessed 11-June-2014].

Wüst, Miriam. 2012. "Early Interventions and Infant Health: Evidence from the Danish Home Visiting Program." *Labour Economics*, 19(4): 484–495.

Appendix

A1. Birth Accounting in Russia

Not only has recorded Russian infant mortality been higher than most of the EU countries, but a more narrow definition of a life births and stillbirths meant that Russia reported lower infant death numbers. Moreover, the high thresholds for a live birth made it convenient to transfer some marginal delivery cases into categories that were not "target indicators" for national statistics (stillbirths) or not counted at all as part of national vital statistics records (late abortions). Consequently, the true picture until very recently almost certainly is worse than that officially reported.

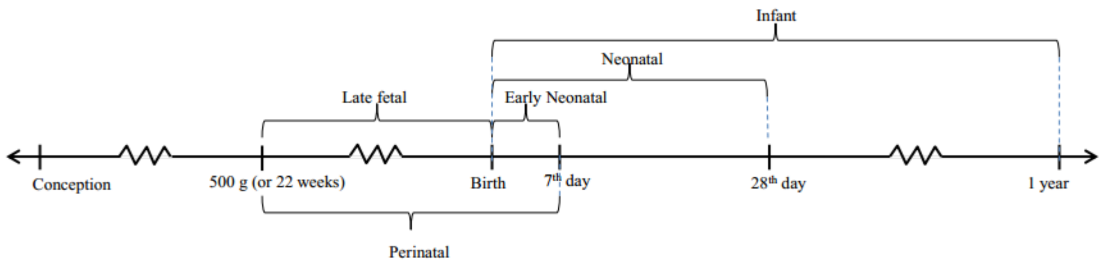
WHO (from its *Health for All* database) defines live births and stillbirths as events occurring irrespective of duration of pregnancy and with the difference between a live birth and still birth being the certain signs of life that the fetus shows after exiting its mother's body.[20]. The permitted lower bound for recording a fetal death is a death during the perinatal period. "The perinatal period commences at 22 completed weeks (154 days) of gestation (the time when birth weight is normally 500 g), and ends seven completed days after birth." (WHO, *Health for All database* definitions). Whatever happens before 22 weeks of pregnancy can be called a miscarriage or abortion.

As defined by WHO, infant mortality, neonatal and early neonatal mortality are the deaths per 1000 live births within the first year, month and week, respectively. Perinatal mortality accounts for all fetal losses in the gestational period between 22 weeks from conception and up to the end of the first week after birth, per 1000 still- and live born infants. Figure 2, taken from Gonzalez (2013) demonstrates the WHO definitions for components of the gestational and infant periods.

The definitions of birth events in pre-2012 Russia were: live born (or stillborn) infants are the infants with the mass of 1000 grams or more, or, if mass is unknown, 35 cm or more, or with duration of pregnancy of 28 weeks or more, or those weighing 500 grams or more in the case of multiple fetuses. In addition, infants weighing 500-1000 grams were recorded as live births only if they survived for more than 168 hours (Ministry of Healthcare of the Russian Federation, 1992). Thus, in practice, the only official difference between a live birth and a stillbirth was whether or not the infant showed any of the signs of life listed in the WHO definition. However, in pre-2012 Russia, the two necessary conditions for officially recording any birth were: 1) its weight exceeds 1000 grams 2) its gestation period exceeds 28 weeks; the only case in which they did not have to be met was if infant survived 168 hours. If an infant was born either on the 27th week of gestation, or weighed

[20]According to WHO, a live birth is "the complete expulsion or extraction from its mother of a product of conception, irrespective of the duration of the pregnancy, which, after such separation, breathes or shows any other evidence of life - e.g. beating of the heart, pulsation of the umbilical cord or definite movement of voluntary muscles - whether or not the umbilical cord has been cut or the placenta is attached. Each product of such a birth is considered live born: a fetal death, which we synonymously term *stillbirth*, is "death prior to the complete expulsion or extraction from its mother of a product of human conception, irrespective of the duration of pregnancy and which is not an induced termination of pregnancy. The death is indicated by the fact that after such expulsion or extraction, the fetus does not breathe or show any other evidence of life, such as beating of the heart, pulsation of the umbilical cord, or definite movement of voluntary muscles."

Figure A1. Components of gestational and Infant Periods



Source: Gonzalez (2013)

999 grams dead or alive and did not survive for 168 hours, it was not included into the official statistics and was signed off as a miscarriage. Importantly, the complications of the mother due to such a birth outcome were also, as a result, omitted in the health statistics, as they no longer were associated with *birth* (Starodubov and Sukhanova, 2013). Since infant mortality has always been a target indicator for Russia by which healthcare performance is measured, as opposed to stillbirths, healthcare providers and officials had an obvious motivation to move marginal live births to less noticed stillbirths (Kvasha and Khar'kova, 2012), and since there was an additional opportunity to completely omit the cases (usually with unfavorable complications for mother and deaths of an infant due to the limited definition of a birth) this created a temptation to undercount the marginal birth cases in two ways.

1) Recording a live birth as a stillbirth;

2) Failure to record in official statistics an infant born (alive or still) weighing not much more than 1000 grams or born slightly after the 27-week boundary.

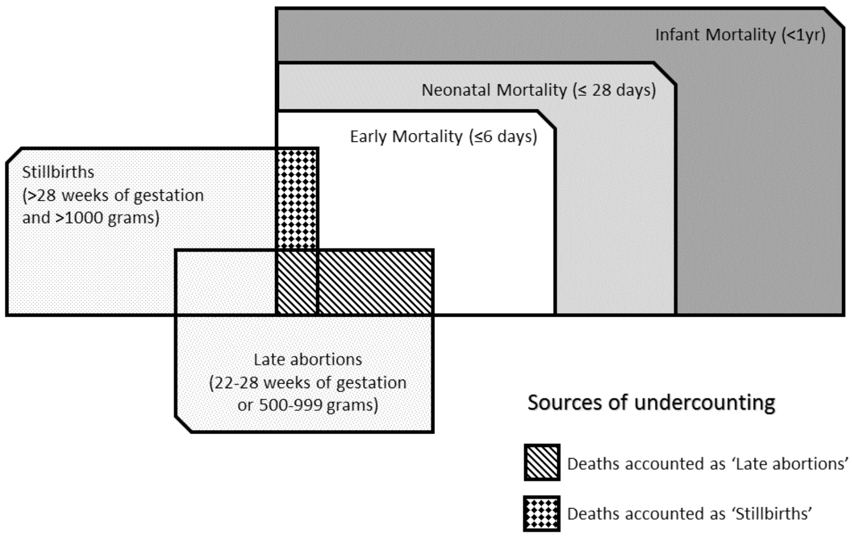
Figure A2 above displays the channels of undercounting.

Fortunately, for internal purposes, the Russian healthcare system tracks of all products of pregnancy born weighing 500-1000 grams and also those with the gestational periods of 22-27 weeks (with the two groups almost fully overlapping). Late abortion data also are available; we obtained access to some of these data and utilize them in our analysis.

A2. New Rules and New Undercounting

One other significant event has coincided with the commissioning of new Perinatal Centers in the 24 regions. In April 2012, the Russian Healthcare Ministry has ordered new criteria for registering live births that are much closer to the WHO standard definition: a fetal discharge is considered a live birth if the fetus' weight is above 500 grams (as opposed to the earlier threshold of 1000 grams); in addition, termination of pregnancy that occurs

Figure A2. Sources of Undercounting of Mortality on Russia



from 22-27 weeks of pregnancy is now considered a live birth (while it was called a *late abortion* before 2012).[21]

As a result, in line with the previous hypotheses, in 2012 the official statistics reported a few interesting changes (as demonstrated in Starodubov and Sukhanova (2013)):

1) 17.6% increase in infant mortality in 2012, of which only 71.8% were accounted for by 500-1000 g infants. Noting that the overall infant mortality trend of the preceding years was declining, the remaining 28.2% increase in infant mortality is surprising;

2) A simultaneous sharp drop in late abortions at 22-27 weeks and a sharp increase in abortions at 12-22 weeks of pregnancy (the share of 22-27 week abortions in total pregnancies dropped from 0.60% to 0.34%, and the respective share of 12-22 weeks' abortions increased from 3.28% to 4.20%, both changes abruptly departed from the preceding smoothly declining trend;

3) The decline in the number of Extremely Low Birth Weight Infants (ELBW) (500-1000 grams) (from 15,692 in 2011 to 10,021 in 2012 and a decline of their share in live and stillbirths from 0.88 to 0.53%);

4) An increase in the number of Very Low Birth Weight Infants (VLBW) (1000-1500 grams) from 11,347 to 13,676 and in their share in live- and stillbirths from 0.64%

[21] Order of Ministry of Healthcare of Russia N1687 27.12.2011, as cited in Starodubov and Sukhanova, 2013.

to 0.73%. This is the first time in recorded Russian history that the number of the VLBW has been larger than the number of ELBW infants.

We believe the dynamics above, almost surely caused by the law change, have revealed certain practices, all under the assumption that there have been no other severe shocks to obstetric practices in 2012. Starting from observations (3) and (4), it is a standard biological pattern that the number of fetuses by weight follows a normal distribution (Salomon, Bernard and Ville, 2007; Starodubov and Sukhanova, 2013) and the fact that they followed an inverse relationship before 2012 can be explained by undercounting. Hospitals did not record terminations of pregnancy with the fetus weighing marginally more than 1000g as real children, but as fetuses, and, presumably, assigned a (false) weight of less than 1000g, preventing the case from entering official statistics as a live birth followed by early neonatal infant death.

Prior to 2012, the live birth criterion used to state that an artificial end to a pregnancy is called an abortion, before the viability of an infant is confirmed. Thus, the procedure for women who delivered infants who were not viable and had a mass close to 1000 grams was likely to be recorded as a *late abortion*. Moreover, in observation (1) it seems likely that much or all of the 28.2% of the increase in infant mortality in Russia after ELBW infants are netted out reflects more accurate childbirth registration, as argued in Starodubov and Sukhanova (2013). With the evidence from (1), (3) and (4), we infer that the average undercounting of infant deaths in Russia before 2012 was at least 28.2% based on old definitions.

From observation (2) we can conclude that re-shifting of marginal cases to the new *late abortions* (at 12-22 weeks) caused the reported reduction in pregnancy termination at 22-27 weeks. 72.4% of the increase in these new *late abortions* category were recorded as due to fetus birth defects and 15.5% due to the mother's health reasons. Although the diagnosis of birth defects is constantly improving, such an abrupt shortening of termination of pregnancy terms is unlikely to be due to sharp improvements in diagnosis, even after many advanced perinatal centers have opened. As for stillbirths, the effect is inconclusive as shown in Figure A2, because from one side, it may be overreported due to marginal neonatal deaths, and from another side underreported, if some stillbirths are placed into *products of late abortions* section.

A number of articles have addressed the problem of undercounting in Russia (Sukhanova (2011); Anderson and Silver (1986); Kvasha and Khar'kova (2012); Andreyev and Kvasha (2002)), and other countries (Gonzalez (2013); Anthopolos and Becker (2010); Penina, Meslé and Vallin (2011)). The authors propose different methods to correct the undercounting or estimate the mortality according to the WHO definition. Gonzalez (2013) adjusts the ratio of early neonatal mortality to fetal deaths. Andreyev and Kvasha (2002) identify unusual proportions of early neonatal deaths conditional on close-to-average perinatal mortality and an indicator for larger undercounting, and correct for it by including births with weights below 1000 grams. Penina, Meslé and Vallin (2011) project the absolute and proportional change of one-week and one-month mortality in 1973 when statistical guidelines in Moldova changed. Anderson and Silver (1986) also utilize the change in reporting rules in 1974 in the Soviet Union to adjust for undercounting.

A3. Tables

Table A1—Full Controls

	(1) 0-1 yr Mortality	(2) 0-28 days Mortality	(3) 0-6 days Mortality	(4) Perinatal Losses	(5) Stillbirths	(6) 28-365 days Mortality
Perinatal Center	-0.367*	-0.346*	-0.280*	-0.473	-0.195	-0.0212
	(0.202)	(0.189)	(0.166)	(0.292)	(0.203)	(0.0971)
Income per Capita, in 1000 rub	0.0191	0.0269	0.0381	0.0257	-0.0113	-0.00774
	(0.0767)	(0.0673)	(0.0581)	(0.0702)	(0.0486)	(0.0334)
Healthcare Financing, in 1000 rub	-0.0144	-0.00495	-0.00124	0.0245	0.0250	-0.00944
	(0.0362)	(0.0238)	(0.0168)	(0.0293)	(0.0268)	(0.0179)
Ob Gyn per 10000 wmn in fert age	-0.0342	-0.0363	-0.199	-0.499	-0.314	0.00212
	(0.218)	(0.215)	(0.258)	(0.442)	(0.283)	(0.121)
Percent of Urban Population	0.00713	0.0286	-0.0537	-0.156	-0.100	-0.0215
	(0.0866)	(0.0950)	(0.0714)	(0.119)	(0.0965)	(0.0462)
Percent below Poverty Line	0.0165	0.0454	0.0289	-0.0270	-0.0580	-0.0289
	(0.0680)	(0.0723)	(0.0463)	(0.0579)	(0.0418)	(0.0262)
Maternity Hospital, count	0.0577	0.107	0.0328	-0.00665	-0.0483	-0.0496
	(0.0765)	(0.0691)	(0.0526)	(0.107)	(0.0831)	(0.0337)
Vodka Consumption per Capita (litres per cap)	0.0440	0.0369	0.0473	0.0749	0.0286	0.00712
	(0.0509)	(0.0380)	(0.0325)	(0.0455)	(0.0323)	(0.0296)
Neonatologists per 1000 infants	-0.0315	-0.0209	-0.00958	-0.0288	-0.0189	-0.0106
	(0.0348)	(0.0301)	(0.0247)	(0.0241)	(0.0152)	(0.0124)
Observations	378	378	378	378	378	378
R^2	0.450	0.385	0.331	0.461	0.446	0.306
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No

Standard errors in parentheses

Errors clustered at oblast level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A2—Adding Fixed Effects and Controls One-by-One

	(1) 0-6 days Mortality	(2) 0-6 days Mortality	(3) 0-6 days Mortality	(4) 0-6 days Mortality	(5) 0-6 days Mortality
Perinatal Center	-0.379*	-0.178	-0.304*	-0.261*	-0.279*
	(0.203)	(0.123)	(0.170)	(0.149)	(0.143)
Constant	3.168***	3.133***	2.950***	3.835***	11.00
	(0.182)	(0.0219)	(0.0679)	(0.0818)	(8.767)
Observations	378	378	378	378	378
R^2	0.011	0.006	0.317	0.630	0.636
OblastFE	No	Yes	Yes	Yes	Yes
TimeFE	No	No	Yes	Yes	Yes
OblastTimetrend	No	No	No	Yes	Yes
Controls	No	No	No	No	Yes

Standard errors in parentheses

Errors clustered at oblast level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A3—Controlling for Lead1

	(1) 0-1 yr Mortality	(2) 0-28 days Mortality	(3) 0-6 days Mortality	(4) Perinatal Losses	(5) Stillbirths	(6) 28-365 days Mortality
Perinatal Center	-0.238	-0.311*	-0.215	-0.454*	-0.228	0.0725
	(0.200)	(0.162)	(0.132)	(0.266)	(0.209)	(0.0939)
Policy Lead 1	-0.244	-0.144	-0.115	0.0392	0.141	-0.0995
	(0.259)	(0.207)	(0.133)	(0.227)	(0.174)	(0.139)
Observations	378	378	378	378	378	378
R^2	0.445	0.374	0.319	0.449	0.434	0.305
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

Errors clustered at oblast level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A4—Controlling for Lead2

	(1) 0-1 yr Mortality	(2) 0-28 days Mortality	(3) 0-6 days Mortality	(4) Perinatal Losses	(5) Stillbirths	(6) 28-365 days Mortality
Perinatal Center	-0.230	-0.301*	-0.206	-0.440	-0.223	0.0709
	(0.201)	(0.163)	(0.133)	(0.267)	(0.209)	(0.0936)
Policy Lead 1	-0.105	0.0208	0.0355	0.275	0.221	-0.126
	(0.236)	(0.179)	(0.103)	(0.210)	(0.167)	(0.136)
Policy Lead 2	-0.254	-0.303	-0.278	-0.433*	-0.149	0.0490
	(0.280)	(0.231)	(0.180)	(0.258)	(0.174)	(0.139)
Observations	378	378	378	378	378	378
R^2	0.447	0.378	0.324	0.452	0.435	0.305
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
Errors clustered at oblast level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A5—Testing With Placebo Policy pre 2012, 24+30 Sample

	(1) 0-1 yr Mortality	(2) 0-28 days Mortality	(3) 0-6 days Mortality	(4) Perinatal Losses	(5) Stillbirths	(6) 28-365 days Mortality
Lead 2	-0.165	-0.206	-0.230	-0.325	-0.0916	0.0418
	(0.259)	(0.215)	(0.168)	(0.237)	(0.160)	(0.135)
Observations	270	270	270	270	270	270
R^2	0.543	0.442	0.444	0.430	0.206	0.326
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
Errors clustered at oblast level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Table A6—Testing With Placebo Policy pre 2011, 24+30 Sample

	(1) 0-1 yr Mortality	(2) 0-28 days Mortality	(3) 0-6 days Mortality	(4) Perinatal Losses	(5) Stillbirths	(6) 28-365 days Mortality
Lead 3	0.0611	-0.0786	-0.0552	0.359	0.424**	0.140
	(0.302)	(0.277)	(0.206)	(0.334)	(0.205)	(0.212)
Observations	216	216	216	216	216	216
R^2	0.532	0.445	0.411	0.433	0.234	0.270
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

Errors clustered at oblast level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Table A7—Testing for Differential Trends, 24+30 Sample

	(1) 0-1 yr Mortality	(2) 0-28 days Mortality	(3) 0-6 days Mortality	(4) Perinatal Losses	(5) Stillbirths	(6) 28-365 days Mortality
Overall Timetrend	-1.307***	-0.819**	-0.455*	-0.818**	-0.389**	-0.489***
	(0.384)	(0.364)	(0.268)	(0.357)	(0.184)	(0.154)
Overall Timetrend X Treated	0.236	0.0192	0.0417	0.263	0.242*	0.217*
	(0.239)	(0.220)	(0.160)	(0.221)	(0.130)	(0.111)
Observations	159	159	159	159	159	159
R^2	0.448	0.376	0.355	0.424	0.277	0.234
Controls	Yes	Yes	Yes	Yes	Yes	Yes
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

Errors clustered at oblast level; Omsk region excluded because treatment happened in 2009

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A8—Distinguishing the Responce if Facilities for Complicated Deliveries Already Exist (in 11 treated regions)

	(1) 0-1 yr Mortality	(2) 0-28 days Mortality	(3) 0-6 days Mortality	(4) Perinatal Losses	(5) Stillbirths	(6) 28-365 days Mortality
Perinatal Center	-0.288	-0.299	-0.128	0.210	0.340*	0.0103
	(0.243)	(0.212)	(0.170)	(0.279)	(0.199)	(0.109)
Perinat Center X No High-Tech Exists	-0.125	-0.249	-0.329	-1.346***	-1.000***	0.124
	(0.351)	(0.352)	(0.273)	(0.288)	(0.277)	(0.156)
Observations	378	378	378	378	378	378
R^2	0.445	0.375	0.323	0.470	0.458	0.311
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
Errors clustered at oblast level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A9—Allowing for Differential Effects if the Center is one of 9 Centers Built From Scratch

	(1) 0-1 yr Mortality	(2) 0-28 days Mortality	(3) 0-6 days Mortality	(4) Perinatal Losses	(5) Stillbirths	(6) 28-365 days Mortality
Perinatal Center	-0.412*	-0.407*	-0.195	-0.114	0.0814	-0.00480
	(0.227)	(0.212)	(0.172)	(0.282)	(0.215)	(0.106)
Perinat Center X Built from Scratch	0.194	-0.00678	-0.229	-0.788*	-0.534	0.201
	(0.362)	(0.365)	(0.306)	(0.468)	(0.380)	(0.153)
Observations	378	378	378	378	378	378
R^2	0.445	0.373	0.320	0.456	0.440	0.312
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
Errors clustered at oblast level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A10—Sbstitution Effect Regressions

	(1) Maternity Units	(2) Maternity Hospital, count	(3) Neonatologists per 1000 infants	(4) Midwives per 10000 wmn in fert age
Perinatal Center	9.004	-0.273*	0.547	0.0636
	(21.11)	(0.154)	(0.865)	(0.146)
Observations	378	378	378	378
R^2	0.250	0.151	0.186	0.199
OblastFE	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No
Controls	Yes	Yes	Yes	Yes

Standard errors in parentheses

Errors clustered at oblast level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

	(1) Ob Gyn per 10000 wmn in fert age	(2) Neonatologists, Count	(3) Midwives, Count	(4) Ob Gyn Doctors, Count
Perinatal Center	-0.0892	1.016	1.595	-7.915
	(0.0770)	(4.513)	(14.01)	(13.92)
Observations	378	378	378	378
R^2	0.103	0.074	0.246	0.022
OblastFE	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No
Controls	Yes	Yes	Yes	Yes

Standard errors in parentheses

Errors clustered at oblast level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A11—Sbstitution Effect Regressions with the "Built from Scratch" Interaction Term

	(1) Maternity Units	(2) Maternity Hospital, count
Perinatal Center	22.92	-0.206
	(22.27)	(0.199)
Perinat Center X Built from Scratch	-39.97	-0.192
	(28.27)	(0.236)
Observations	378	378
R^2	0.259	0.155
OblastFE	Yes	Yes
TimeFE	Yes	Yes
OblastTimetrend	No	No
Controls	Yes	Yes

Standard errors in parentheses

Errors clustered at oblast level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A12—Perinatal Centers and Maternity Hospitals Interaction

	(1) 0-1 yr Mortality	(2) 0-28 days Mortality	(3) 0-6 days Mortality	(4) Perinatal Losses	(5) Stillbirths	(6) 28-365 days Mortality
Perinatal Center	-0.455	-0.543*	-0.243	-0.369	-0.121	0.0881
	(0.328)	(0.302)	(0.225)	(0.336)	(0.307)	(0.136)
Maternity Hospital, count	0.00623	0.0616	-0.00213	-0.0769	-0.0843	-0.0553
	(0.0740)	(0.0676)	(0.0567)	(0.115)	(0.0861)	(0.0356)
Mat. Hosp X Perinatal Center	0.0413	0.0553	-0.0119	-0.0149	-0.00226	-0.0140
	(0.0855)	(0.0758)	(0.0536)	(0.0670)	(0.0709)	(0.0315)
Observations	378	378	378	378	378	378
R^2	0.445	0.376	0.318	0.450	0.436	0.312
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
Errors clustered at oblast level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A13—Perinatal Centers and Change in Neonatologists in the First Year of Treatment

	(1) 0-1 yr Mortality	(2) 0-28 days Mortality	(3) 0-6 days Mortality	(4) Perinatal Losses	(5) Stillbirths	(6) 28-365 days Mortality
Perinatal Center	-0.425*	-0.478**	-0.322*	-0.425	-0.0902	0.0523
	(0.212)	(0.196)	(0.166)	(0.289)	(0.207)	(0.109)
Change in Neonatologists in 1st yr of Treatment X PC	0.0220*	0.0185*	0.0127	0.00981	-0.00384	0.00348
	(0.0116)	(0.0110)	(0.00870)	(0.0147)	(0.0118)	(0.00496)
Observations	378	378	378	378	378	378
R^2	0.448	0.377	0.321	0.450	0.435	0.310
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
Errors clustered at oblast level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE A14—DIFFERENCE BETWEEN URBAN AND RURAL

	(1) Infant Mortality Urban	(2) Infant Mortality Rural	(3) Infant Mortality Urban	(4) Infant Mortality Rural
Perinatal Center	-0.227	-0.617*	-0.679**	-0.656
	(0.300)	(0.333)	(0.325)	(0.408)
Observations	357	357	546	546
R^2	0.370	0.241	0.190	0.145
OblastFE	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No
Controls	Yes	Yes	Yes	Yes

Standard errors in parentheses

Errors clustered at oblast level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

TABLE A15—BIRTH RATES IN TREATED AND NEIGHBORING REGIONS

	(1) Births per 1000 people	(2) Births per 1000 people	(3) Births per 1000 people	(4) Births per 1000 people
Perinatal Center	0.0728		0.0929	
	(0.108)		(0.125)	
Perinatal Center in Neighboring Oblast		-0.167		-0.145
		(0.173)		(0.207)
PC X Close to Border			-0.0619	
			(0.155)	
PC in Neighb. Oblast X Close to Border				0.0954
				(0.180)
Observations	378	210	378	174
R^2	0.567	0.468	0.567	0.469
OblastFE	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No
Controls	Yes	Yes	Yes	Yes

Standard errors in parentheses

Errors clustered at oblast level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A16—Test for Endogenous Undercounting, Birth Weights

	(1) % Births 500-749g	(2) % Births 750-999g	(3) % Births 1000-1499g	(4) % Births 1500-1999g	(5) % Births 2000-2499g	(6) % Births 2500-2999g	(7) ELBW share	(8) ELBWshare/LBWshare
PC Opening in 2012	0.0391	0.0176	0.0782	-0.0695	0.0191	0.0663	0.0567	0.0314
	(0.0247)	(0.0307)	(0.0479)	(0.0806)	(0.161)	(0.334)	(0.0465)	(0.0297)
Treated PC in 2012	0.105**	-0.0138	-0.0791	-0.235	-0.635*	-3.128***	0.0917	0.0730
	(0.0509)	(0.0634)	(0.0989)	(0.166)	(0.333)	(0.689)	(0.0959)	(0.0613)
Year Dummy 2012	0.0465***	0.00351	0.0841***	0.0384	0.00649	-0.232**	0.0500***	0.0145
	(0.00813)	(0.0101)	(0.0158)	(0.0265)	(0.0531)	(0.110)	(0.0153)	(0.00977)
Constant	0.0368	0.243***	0.668***	1.516***	4.307***	16.83***	0.280***	0.126***
	(0.0352)	(0.0438)	(0.0683)	(0.115)	(0.230)	(0.476)	(0.0663)	(0.0423)
Observations	166	166	166	166	166	166	166	166
R^2	0.642	0.644	0.796	0.806	0.875	0.930	0.623	0.545
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A17—Test for Endogenous Undercounting, Late Abortions

	(1) Delivery at 22-27 weeks	(2) % Born Dead at 22-27 Weeks	(3) LBW share (1000-2000g)	(4) VLBW share (1000-1500g)
PC Opening in 2011	5.168	7.851*	0.0354	-0.0311
	(9.070)	(4.160)	(0.118)	(0.0465)
Treated PC in 2011	380.4***	-21.63**	0.532*	0.266**
	(21.04)	(9.651)	(0.274)	(0.108)
Year Dummy 2011	9.915***	1.007	0.0479	0.0394**
	(3.449)	(1.582)	(0.0449)	(0.0177)
Constant	72.04***	69.05***	1.426***	0.430***
	(14.63)	(6.711)	(0.190)	(0.0750)
Observations	166	166	166	166
R^2	0.993	0.709	0.687	0.722
Controls	Yes	Yes	Yes	Yes

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A18—Policy Effect on Maternal Outcomes, 1

	(1) Maternal Mortality (deaths per 100000 births)	(2) Anemia	(3) Illnesses of the Cardiovascular System	(4) Diabetes	(5) Illnesses of the Urogenital System	(6) Peritonitis after Cesarean (per 1000 cesareans)	(7) Sepsis	(8) Uterus Tearing	(9) Perineal Rupture of 3rd-4th Degree
Perinatal Center	7.609**	12.69	3.932	1.045**	6.688	0.125**	-0.143	0.0216	-0.0419
	(3.372)	(8.467)	(5.430)	(0.457)	(5.766)	(0.0607)	(0.172)	(0.0197)	(0.0641)
Observations	318	324	324	324	324	324	324	324	324
R^2	0.171	0.158	0.034	0.489	0.206	0.070	0.158	0.067	0.033
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

Errors clustered at oblast level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A19—Policy Effect on Maternal Outcomes, 2

	(1) Post-Labor Bleeding	(2) Labor Irregularities	(3) Bleeding due to a Premature Detachment of Placenta	(4) Obstructed Labor	(5) Bleeding due to Placenta Preria	(6) Bleeding due to Coagualtion Disorder	(7) Swelling and Hypertension	(8) Eclampsya and Pre-ecplampsya
Perinatal Center	0.570	0.930	0.402	-12.50**	0.0979	0.176	6.005	0.411
	(0.627)	(4.000)	(0.441)	(5.443)	(0.148)	(0.126)	(7.674)	(4.170)
Observations	324	324	324	324	324	324	324	324
R^2	0.315	0.241	0.062	0.150	0.031	0.046	0.163	0.016
OblastFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TimeFE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OblastTimetrend	No	No	No	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

Errors clustered at oblast level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A20—Summary Statistics in 2007 (Before Treatment)

	Never Treated	To-Be-Treated	Treated	Total
0-1 yr Mortality	10.42	9.307	9.599	9.773
	(3.805)	(2.909)	(2.459)	(3.132)
0-28 days Mortality	5.750	5.503	5.497	5.586
	(1.871)	(2.424)	(1.679)	(2.021)
0-6 days Mortality	3.933	3.823	3.658	3.812
	(1.409)	(1.942)	(1.193)	(1.558)
Perinatal Losses	9.450	9.130	9.148	9.244
	(2.262)	(2.419)	(1.539)	(2.120)
Stillbirths	5.506	5.333	5.486	5.437
	(1.606)	(1.033)	(0.952)	(1.227)
28-365 days Mortality	4.670	3.803	4.102	4.187
	(2.639)	(1.213)	(1.223)	(1.847)
Births, count	11208	24027.2	23886.4	19608.7
	(9930.0)	(20881.4)	(14561.4)	(16918.4)
Life Expectancy at Birth (yrs)	65.90	67.69	66.65	66.78
	(3.075)	(2.776)	(1.867)	(2.735)
Income per Capita, in 1000 rub	11.96	11.27	10.34	11.23
	(8.427)	(6.349)	(2.680)	(6.369)
Healthcare Financing, in 1000 rub	7.491	5.001	5.059	5.868
	(7.669)	(3.287)	(2.779)	(5.201)
Ob Gyn per 10000 wmn in fert age	5.436	4.773	5.138	5.106
	(1.407)	(1.011)	(0.854)	(1.145)
Percent of Urban Population	67.14	68.56	72.90	69.34
	(14.23)	(12.60)	(10.89)	(12.79)
Percent below Poverty Line	20.30	16.05	16.50	17.63
	(8.866)	(5.134)	(4.523)	(6.724)
Maternity Hospital, count	1.643	2.367	3.292	2.390
	(1.747)	(3.764)	(2.196)	(2.810)
Vodka Consumption per Capita (litres per cap)	12.86	11.87	12.46	12.38
	(4.077)	(4.277)	(4.061)	(4.117)
Neonatologists per 1000 infants	32.90	29.73	35.99	32.64
	(11.32)	(7.478)	(8.557)	(9.486)
Observations	82			

mean coefficients; sd in parentheses

Table A21—Summary Statistics in 2013 (After Treatment)

	Never Treated	To-Be-Treated	Treated	Total
0-1 yr Mortality	9.866	8.000	7.800	8.594
	(4.415)	(2.165)	(1.515)	(3.137)
0-28 days Mortality	5.797	5.033	4.492	5.143
	(2.626)	(1.892)	(1.013)	(2.047)
0-6 days Mortality	3.790	3.297	2.904	3.355
	(2.259)	(1.501)	(0.765)	(1.683)
Perinatal Losses	10.26	9.383	9.483	9.717
	(2.775)	(2.987)	(1.506)	(2.565)
Stillbirths	6.503	6.123	6.604	6.395
	(1.536)	(1.921)	(1.399)	(1.644)
28-365 days Mortality	4.069	2.967	3.308	3.451
	(3.178)	(0.770)	(0.909)	(2.029)
Births, count	13552.7	28958.8	27977.4	23292.2
	(12705.8)	(28053.2)	(18589.2)	(21956.6)
Life Expectancy at Birth (yrs)	69.18	70.80	69.83	69.96
	(2.934)	(2.584)	(1.815)	(2.590)
Income per Capita, in 1000 rub	25.13	23.84	21.91	23.73
	(13.84)	(8.540)	(4.755)	(9.962)
Healthcare Financing, in 1000 rub	12.14	10.62	8.942	10.66
	(8.581)	(5.750)	(1.675)	(6.266)
Ob Gyn per 10000 wmn in fert age	5.396	4.761	4.998	5.051
	(1.471)	(1.056)	(0.788)	(1.175)
Percent of Urban Population	66.35	69.17	74.07	69.60
	(15.20)	(12.82)	(10.25)	(13.27)
Percent below Poverty Line	15.56	12.34	13.06	13.67
	(6.582)	(3.594)	(3.038)	(4.896)
Maternity Hospital, count	1.276	2	2.583	1.916
	(1.334)	(3.384)	(2.244)	(2.519)
Vodka Consumption per Capita (litres per cap)	9.931	8.868	9.075	9.300
	(4.404)	(3.843)	(2.977)	(3.815)
Neonatologists per 1000 infants	30.38	28.78	34.85	31.10
	(10.41)	(7.722)	(6.816)	(8.799)
Observations	83			

mean coefficients; sd in parentheses

Table A22—Summary Statistics Full Sample

	count	mean	sd	min	max
0-1 yr Mortality	581	8.447761	3.03274	0	23.9
0-28 days Mortality	581	4.883685	2.115317	0	18.1
0-6 days Mortality	581	3.266017	1.712627	0	14
Perinatal Losses	581	8.610403	2.512963	0	19.9
Stillbirths	581	5.351271	1.505431	0	11.1
28-365 days Mortality	581	3.564076	1.599954	0	17.9
Perinatal Center	581	.1153184	.3196811	0	1
Births, count	581	21871.61	19736.67	641	135853
Life Expectancy at Birth (yrs)	579	68.33382	2.870074	57.5	78.84
Income per Capita, in 1000 rub	581	17.40301	8.996022	4.0059	66.276
Healthcare Financing, in 1000 rub	581	8.047805	5.973791	1.7235	43.73544
Ob Gyn per 10000 wmn in fert age	581	5.135663	1.204077	2.8	10.02
Percent of Urban Population	581	69.26351	13.2023	26.7	100
Percent below Poverty Line	576	15.30972	5.333456	5.6	45.3
Maternity Hospital, count	581	2.156627	2.67902	0	19
Vodka Consumption per Capita (litres per cap)	581	11.18373	4.261653	0	24.3
Neonatologists per 1000 infants	581	32.20998	9.206235	0	61.4
Observations	581				

A4. The Visual

We plot a range of graphs for all our outcome variables and observe the changes in trends during policy implementation. We indicate the two larger policy changes in 2011 and 2012 with red vertical lines. For a more natural exposition, each year's marker is put at the end of the year (e.g. 2012 data are shown at the start of 2013), for all our outcome variables are *year-end totals*. Infant mortality data are presented in Figures A3 and A4.

Figure A3. Mortality Trends

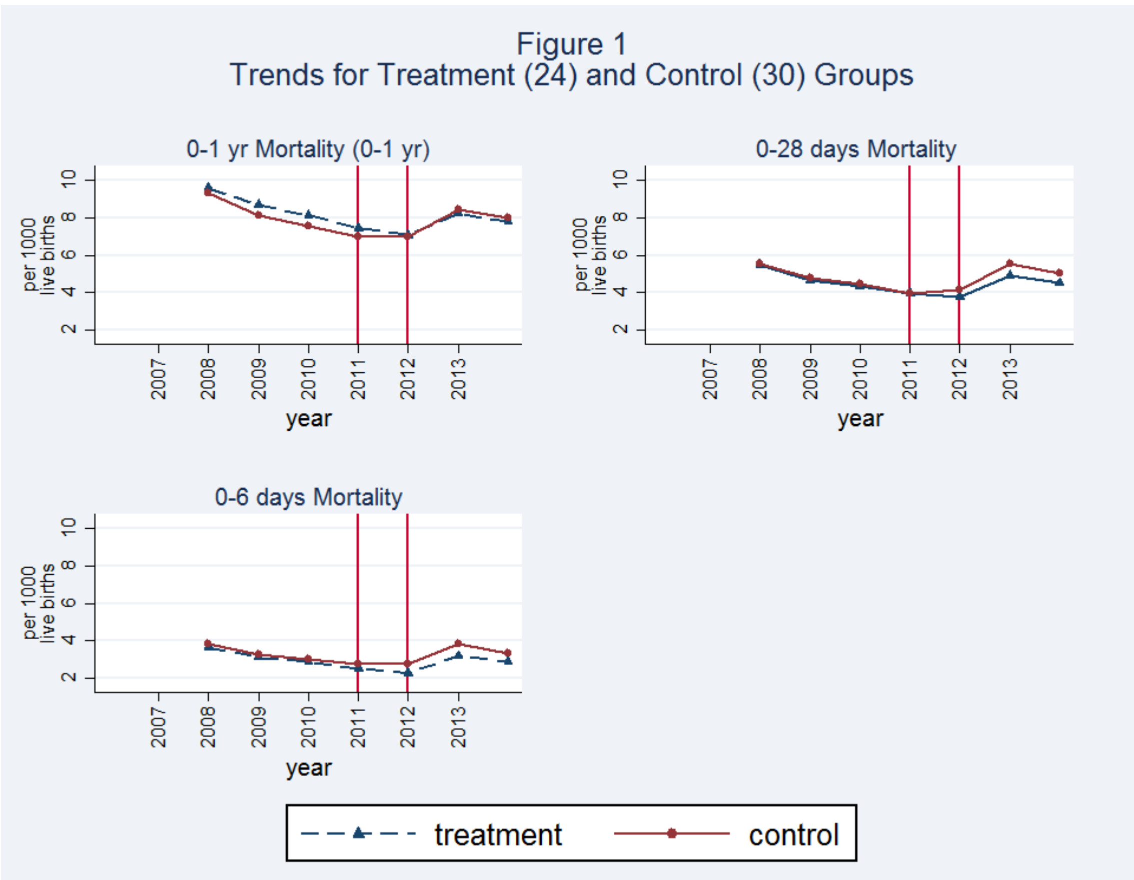
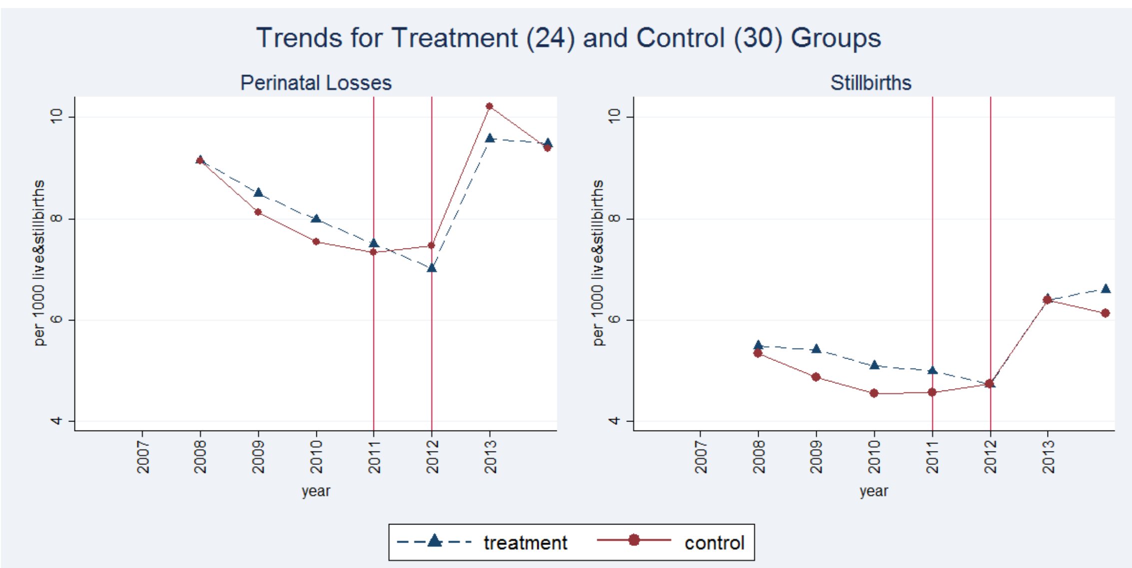


Figure A3 shows three key mortality outcomes for live born infants (measured by the mortality rate per 1000 live births). Trends in mortality are parallel and declining in both groups, prior to treatment. After 2011 and 2012 the trends diverge: as the control group rates increase on average, the treatment group rates continue to fall. After 2012, the mortality rate increases for both groups due to the change in birth accounting standards.

In Figure A4 the denominator in the rate of both perinatal mortality or stillbirths is the sum of all live and stillbirths. We see a slightly different pattern than in Figure A3, as the perinatal mortality and stillbirths in isolation are both higher on average in the 24 treated oblasts before intervention. Still, the trend is almost parallel in the years prior to the first treatment in 2010. After 2011, the trends diverge for perinatal mortality and converge for stillbirths. The possibility that oblasts with a functioning new perinatal center either enjoyed more infants surviving their perinatal period and/or more live births per stillbirths, can explain the visible pattern. Moreover, stillbirths declined more in the 2011-2012 which potentially show improved undercounting and match our findings in section *D*. We are more confident on that some regions would put more efforts on undercounting stillbirths in 2012, since underreporting with regard to late abortions would be no longer possible. In this case, in the absence of perinatal centers stillbirths would have increased to a higher value.

Figure A4. Trends for Perinatal Mortality and Stillbirths



Furthermore, in Figure A5 we include other parameters related to population health, but not necessarily directly related to the functioning of the perinatal center to compare the trends.[22] If there were other general improvements in quality of healthcare or living standards in the treated oblasts that affected both infant outcomes and outcomes for the

[22]Infant mortality affects the estimates of life expectancy at birth, but there are many other factors that also influence life expectancy. Opening of perinatal centers in 2011 and 2012 should not affect life expectancy directly (or at least in the first two years after treatment).

rest of population, the positive result would also show up as increased life expectancy at birth, or a higher proportion of normal births. Indeed, the dynamics of life expectancy at birth are not puzzling. They are parallel for pre-treatment years and remain so over the treatment period. The proportion of normal births has been volatile and clearly does not show any higher improvement in the treated regions. We can be confident that in case of a mortality reduction, it did not happen due to the increased proportion of normal births.

Figure A5. Trends for Other Variables