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Impact of TB Epidemic on Worker and Firm Productivity: Regional Perspective

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Abstract

This paper investigates the indirect economic impact of tuberculosis epidemic in one of the high burden countries, focusing on the productivity at individual level measured by the average wages and at firm level measured by the average total factor productivity (TFP). We use unique administrative data collected at the level of firms and regions for the period 2003-2009 and find that the ongoing tuberculosis (TB) epidemic has considerable indirect economic costs in terms of lost productivity and related inefficiencies. First of all, both firms and individuals in regions with higher TB prevalence have significantly lower TFP and wages. Moreover, consistent with the Compensating Wage Differentials theory and after controlling for the TB prevalence, the risk of contracting the disease - TB incidence rate - is associated with higher wages and higher productivity - a kind of premium for individuals and firms to operate in a risky environment. The latter can also be viewed as a source of inefficiency as this may prevent firms from entering more competitive markets. Additional analysis reveals strong spatial effects which are consistent with the infectious nature of the diseases and emphasize the importance of containing the epidemic. Overall, we estimate that a 10% decrease in the TB prevalence can lead to a 1.05% gain in GDP: 0.15% in terms of higher individual productivity and 0.89% in terms of firms' productivity.

1 Introduction

Worldwide tuberculosis (TB) is one top ten leading causes of deaths and the leading cause of death from one single infectious agent. And, although the epidemic is mostly affecting developing countries, the globalisation of trade and migration flows ensures that TB remains a global threat requiring attention in both developing and developed countries. In September 2018, the United Nations held its first high-level meeting on TB at its headquarters in New York. The need for immediate action to combine efforts towards the goal of ending the TB epidemic by 2030 was highlighted even in the title of the meeting - "United to End TB: An Urgent Global Response to a Global Epidemic". Among the targets of the Sustainable Development Goal 3 "Good Health and Wellbeing" is a reduction of the TB deaths by 90% and of TB incidence rates by 80% by year 2030 as compared to year 2015. The End TB Strategy goes further to reduce the TB deaths by 95% and TB incidence rates by 90% by year 2035 (WHO 2018). In 2017, 10 million people were infected and 1.6 million of people died from this disease (WHO 2018). Majority of the population (over 95%) infected with tuberculosis live in the low- and middle-income countries. According to the World Health Organization, in the developing countries tuberculosis has become the third leading cause of death among women of reproductive age.

In addition to being a treacherous infectious disease, tuberculosis draws other increasingly high risks. In particular, increases in the rates of multi-drug resistant (MDR) and extra-drug resistant (XDR) forms of tuberculosis have been reported in almost every country. Moreover, tuberculosis has become tightly connected with HIV/AIDS. It is estimated that around 25% of all people with HIV positive status die from tuberculosis every year. Finally, tuberculosis is not only adversely affecting health of people in the most productive age group, but at the same time, brings numerous undesirable social consequences. In 2009 approximately 10 million children became orphans as a result of their parents' deaths from tuberculosis (WHO 2009).

After the collapse of the USSR, Ukraine as well as the other post-Soviet countries have experienced a continuous worsening of the population health, including an enormous growth of tuberculosis prevalence (Vassal et al. 2009). This has been aggravated by a substantial underfinancing of organizations responsible for tuberculosis control (Hammers & Downs 2003), an increased poverty among population, and an abolishment of social security benefits for tuberculosis patients such as disability pensions or job security (Drobniewski et al. 2004). Ukraine is a country which has had the TB incidence rate of 127 per 100,000 population in 2004-2005 reducing to 91 by year 2015[1] and to 84 by 2017 (WHO 2018), while still being among the 30 countries with the highest burden of multi-drug resistant TB (16% of new registered cases being MDR TB compared to the average of 3.8% for this group of countries) (WHO 2015) or 30 per 100,000 population in 2017 (WHO 2018). The situation has been further complicated by the spread of the HIV/AIDS epidemics - Ukraine has the most severe epidemics contributing more than 20% of the newly diagnosed cases in Europe and Eurasia region (Vassal et al. 2009). With more than 70% of Ukrainian population living in citie,s which also contributes to higher risk of spread of disease due to a larger number of prisons, illegal immigrants infected with HIV or tuberculosis, homeless and mobile population (Codecasa & Migliori 2004). As a result, tuberculosis has an alarming spread rates in the area. Incidence rates of all forms of tuberculosis in Ukraine have increased from 41 in 1990 to 101 per 100,000 of population in 2010 (WHO 2010). Moreover, the ongoing Russian aggression

[1] http://data.worldbank.org/indicator/SH.TBS.INCD?locations=UA

which started in summer of 2014 in two of regions - Donetsk and Luhansk - which have historically been the most TB burdened regions in the country, with the relevant effects including, among others, disturbance to the TB surveillance and treatment due to interruptions with the supply of medicine in occupied territories - a factor directly linked to the development of MDR and XDR forms of TB. Currently, there are 1.5 mln internally displaced persons in Ukraine [2] who are more likely to have been either infected by or in contact with those infected, be unemployed, live in poverty and have worse access to health care.

In order to stop epidemics of tuberculosis and reduce the incidence rate a number of directly targeted programs have been developed all over the world: for example, DOT (directly observed treatment), immunization with BCG medicine (Bacilli Calmette Guerin), and others. There are also indirect programs which target incomes of poor families, educate population on healthy life styles, etc. All these programs require considerable public funds. And in order to make decisions on which programs to implement, the governments have to compare their costs to the costs of doing nothing. The economic burden of TB comprises of several components: (i) direct cost of treatment, (ii) loss of GDP related to the reduction in productive population due to premature death, (iii) lost productivity due to the illness of the directly affected individuals, (iv) lost productivity of care-providers and other family members. In addition, if people do not expect to live long, they do not invest either in their own education or in the education of their children, and they do not have a motivation to engage in entrepreneurial activities. This has a further dampening effect on the productivity of the affected country workforce and as a result on the overall economic development. At the same

[2] https://reliefweb.int/report/ukraine/national-monitoring-system-report-situation-internally-displaced-persons-june-2018

time it is well established that TB has its roots in poverty and deprivation, and, therefore, any study of the impact of the TB epidemic on productivity has to account for a possibility of a reverse causality.

This study relies on two unique data sets which allow combining epidemiological data on TB-related indicators with the socio-economic information from administrative statistics for small administrative units (rajons) in Ukraine to estimate the cost of TB epidemics. Out of the overall 669 rajons, the resulting analytical sample contains 609 over the period from 2003 to 2009. Using two measures describing TB epidemics - prevalence and incidence rate per 100,000 population and applying fixed effects modeling we find that indeed the ongoing TB epidemic brings about considerable indirect economic costs in terms of lost productivity and related inefficiencies. First of all, both firms and individuals in regions with higher TB prevalence have significantly lower TFP and wages. For example, an increase in TB prevalence rate by 10 percent leads to a 0.3% decrease in wages and 0.9% lower total factor productivity. Moreover, consistent with the Compensating Wage Differentials theory and after controlling for the prevalence of the TB, the risk of contracting the disease - TB incidence rate - is associated with higher wages and higher productivity - a kind of premium for individuals and firms to operate in risky environment. The latter can also be viewed as a source of inefficiency as this may prevent firms from entering more competitive markets. Additional analysis reveals strong spatial effects which are consistent with the infectious nature of the diseases and emphasize the importance of containing the epidemic. Overall, we estimate that the gain from reducing the TB prevalence by 10% is associated with a 2.4 bln gain in terms of individual productivity which is equivalent to 0.15% of GDP in year 2014 and 0.89% of GDP gain in terms of total factor productivity of firms.

The paper proceeds as follows. Section 2 is devoted to a more detailed description of the recent TB dynamics in Ukraine. Section 3 continues with the review of the existing literature, followed by the description of the data and methodology in Sections 4 and 5 respectively. Estimation results are provided in Section 7 with Section 8 devoted to their discussion and robustness analysis. Section 9 concludes.

2 Background

2.1 Recent Tuberculosis Dynamics in Ukraine

TB has been imposing a serious burden on Ukraine since the collapse of the Soviet Union. While the incidence rate was 31.9 in 1990, in 1995 WHO officially announced TB epidemic in Ukraine, and in 2004-2005 it reached its peak with the incidence rates of 127 cases per 100 000 population[3]. Only in 2012 Ukraine left the list of 22 high TB burden countries. However, at present it is still on the list of high burden countries with regards to MDR-TB (WHO 2015). Moreover, the statistics at international level does not quite correspond to the one available internally. According to the State Service of Ukraine, in 2012 the first-diagnosed incidence rate was 68.2 per 100 000 population (67.3 in 2011 and 68.5 in 2010). The incidence rate in rural areas was much higher, than in urban (73.8 versus 65.5). Traditionally, Kherson (107.9 per 100 thousand population), Dnipropetrovsk (92.9), Mykolaiv (87.3), Odessa(94.0), Lugansk (79.1), Kirovograd (77.8) regions had higher than national average rates of tuberculosis in 2012.

The situation is complicated by the fact that 30% of HIV-infected Ukrainians suffer from TB, and 40% of these people will die, according to the data.

[3]http://data.worldbank.org/indicator/SH.TBS.INCD?locations=UA

Unfortunately, the indicator of coverage of HIV testing among patients with TB remained at 86.4% according to "Ukrainian Center for Socially Dangerous Disease Control of the Ministry of Health of Ukraine". While the figure was 98.8% in Mykolaiv, 97.6% in Vinnytska, and 98.5% in Sevastopol regions, Khmelnitsky region covered only 10.6% of TB patients with testing for HIV in 2012.

One of the indicators of efficiency of TB targeting policies and treatment is the share of cases with repeated treatment among the patients. This indicator has been growing in 2010-2012 - 26.4%, 26.9%, 30.3% respectively, above the level of the threshold of 30%.

Another disturbing indicator distinctive of Ukraine is the number of Multi-drug and Extra-drug Resistant TB (X/MDR-TB) cases. It was estimated at 7100 cases out of all the registered with active tuberculosis, according to the World Health Organization. After the introduction of modern methods of diagnostics, the number of verified cases with MDR-TB grew from 329 in 2009 to 6934 in 2012. However, the number of MDR-TB suspected cases revealed the following trend: 750 in 2009, 779 in 2010, 1208 in 2011 and 1477 in 2012. This negative trend suggests that there are drawbacks in diagnostics of this form of TB.

While the prevalence rate of all-forms of active tuberculosis decreased in 2012, as compared to 2011, by 12.4% (from 155.1 for 100 000 population in 2011 to 135.9 in 2012), the effectiveness of treatment is still substantially lower than the one recommended by the WHO (55% vs 85% recommended). Higher effectiveness is observed in Volyn (79.5%), Ternopil (77.9%), Chernihiv (77.3%), Lviv (72.2%), and Ivano-Frankivsk (70.5%) regions. At the same time Kherson (48.5%), Dnipropetrovsk (47.2%), Kharkiv (45.2%), Luhansk (37.3%) regions, and Crimea (47.2%) are lagging behind. The most disturbing rates were documented in health care facilities of the State Penitentiary Service of Ukraine - 34.8%.

Behind these numbers one will find high shares of unsuccessful tuberculosis treatments (19.6%), interrupted treatments (7.5%), and deaths (14.1%). Overall, in 2012 the death rate from TB was 15.1 per 100 000 of population.

Unemployed people of working age are at the highest risk of contracting the disease - 55.4% of all newly diagnosed cases in 2012, pensioners and blue-collar workers follow with 12.2%, 12.1% respectively, first-diagnosed people registered in medical facilities of other ministries - 3.9% , white-collar workers - 2.8%, students of all education institutions - 3.2%, health workers - 1.6%, persons without permanent place of residence - 2.0%, agricultural sector workers- 1.1%, private entrepreneurs - 0.7% , returned from places of detention, - 0.6%, others - 3.7%.

Current National Tuberculosis Program (NTP) was adopted in 2007, when directly observed treatment was adopted as national strategy to control tuberculosis. In the same year the National Council for the Prevention of TB and HIV/AIDS and the Ministry of Health‘s Committee on HIV/AIDS and Other Socially Dangerous Diseases were established. However, with the Russian invasion, the established mechanisms of diagnostics and treatment in the Eastern regions (historically most affected by the Epidemics) have been disturbed and further improvement in the situation is endangered.

2.2 Related Literature

There is no doubt that healthier people are more productive as they are capable of exerting more effort, and are less likely to take sick leaves (Strauss & Thomas 1998). Evidence in the literature suggests consistent findings of strong positive impact of population’s health on economic growth. However, the findings are difficult to compare because of the variation in health measures. In a number of studies life expectancy has been used in the economic growth models as a measure of population's health. They show that a one-year improvement in the life expectancy of the population contributes to an increase in economic growth by approximately 4-7% (Barro 1996, Barro & Lee 1994, Barro & Sala-I-Martin 1995, Bloom & Canning 2000). However, it is documented that the effect of life expectancy or other measures of population health on economic growth is heterogeneous. In particular, in less developed countries health has a larger impact on economic growth compared to education; while in more developed countries it is education that plays more important role in the economic growth of the country (**?**). In addition, there is an evidence of diminishing returns to health (Bhargava et al. 2001).

Some of the studies in this literature investigate the impact of specific diseases on economic growth. For example,estimates from a cross-country analysis over the period from 1965 to 1990 show that countries with intensive malaria grew 1.3% less per person per year and that a 10% reduction in malaria was associated with a 0.3% higher growth (Gallup & Sachs 2001). Brainerd and Siegler (2003) investigate the influence of 1918 influenza on per capita income growth across different U.S. states and find positive association during 1920s. Concerning tuberculosis, Grimard & Harling (2004) find that a decrease of tuberculosis incidence rate by 10% can be associated with an increase of income per capita by 0.2-0.4%. Grimard & Harling (2004) estimating the augmented Solow growth model on a sample of 91 countries over the period from 1981 to 2000 find that there is a persistent effect of 0.2 to 0.4 percent lower growth for every 10 % higher incidence of TB.

Eloquent results can be driven from Lotka-Voltera type modeling of TB epidemics applied to Solow-Swan growth model. In high-income countries infectious diseases affect productive capacity of the economy and the size of labor force differently than in all the other countries: while in prosperous country infection quickly eradicates, in less wealthy countries shot of diseases will end up in lower capacity population (Doriana & Simmons 2005). Generally, these are poor people and poor countries, who are actually burdened with the tuberculosis. Estimates of TB costs from Thailand (Kamolratanakul et al. 1999) and Philippines (John et al. 2005), as well as for immigrant patients inthe Netherlands (Sandra et al. 2009), support this argument: infected people spend their savings, take loans from banks, borrow from relatives, and sell property in order to survive.

However, the above mentioned studies are subject to one major criticism - potential endogeneity due to reverse causality as rising incomes may be the causes of better prevention, treatment, and thus, higher life expectancy. To illustrate, (Datta & Reimer 2013) study of the 100 endemic countries over the 17-year period shows that most of the earlier found effect of malaria is due to reverse causality, as rising incomes of the households allow for an increased prevention and treatment of malaria. Similarly, Acemoglu and Johnson exploiting the major international health improvements from 1940s find that life expectancy has very small impact on economic performance (Acemoglu & Johnson 2007). This concern is even more serious in the case of tuberculosis as its onset is exceptionally closely related to poverty (Kamolratanakul et al. 1999, John et al. 2005, S. et al. 2006). Moreover, upturns in TB cases and deaths are very likely in the periods of economic recessions (Nimalan & Dye 2010).

Despite the mentioned problem the attempts to estimate the economic costs of serious diseases are ongoing. For example, Grimard & Harling (2004) address the issue of endogeneity in a cross-country setting by employing random effects GLS and fixed-effects LSDV models, as well as the correlated-effects GLS to model the impact of the average TB incidence on five-year economic growth.

This paper contributes to the literature in several ways. First of all, it turns to a regional level analysis in a one-country addressing the concerns about the differences in the health systems which is pertinent to the cross-country studies. Second, it studies two measures of productivity - total factor productivity of all firms in the region and the average regional monthly wage as a measure of individual productivity. Fourth, it compares the impact of the prevalence of TB to that of the incidence, as they have different interpretations in the context of productivity. Finally, it takes into account spatial aspects of the TB epidemics and productivity.

3 Methodology

3.1 Modeling Productivity

The destructive impact of tuberculosis on the economy is derived from two measures of productivity - a regional total factor productivity (TFP), which is a labor weighted-average TFP of all firms in the region, and an average regional monthly wage. The TFP is often seen as a driver of economic growth, while the average regional wage reflects a marginal product of labor when markets are competitive. The first has mostly been the subject of the analysis in the fields of industrial organization and international trade while the latter - of labor economics. Thus, our models will rely on sources from both fields, subject to data availability. To address the issue of endogeneity we will estimate the effect of TB measures and other control variables on outcomes, exploiting the panel structure of the data.

Therefore, the models of individual and total factor productivity productivity will define respectively the average wage rate ARW_{it} and total factor productivity TFP_{it} for raion i at time t as a function of variables describing TB situation TB_{it}, average quality of human capital and relevant socio-economic characteristic in the following way:

$$\ln ARW_{it} = \alpha_0 + \alpha_1 \ln TB_{it} + \alpha_2 Educ_{it} + \alpha_3 {Educ_{it}}^2 + \alpha_4 \ln Death_{it} \\ + \alpha_5 Unempl_{it} + \alpha_6 Urban_{it} + \alpha_7 Density_{it} + \epsilon_{it} \quad (1)$$

$$\ln TFP_{it} = \beta_0 + \beta_1 \ln TB_{it} + \beta_2 Educ_{it} + \beta_3 {Educ_{it}}^2 + \beta_4 \ln Death_{it} \\ + \beta_5 Unempl_{it} + \beta_6 Exp_{it} + \beta_7 Imp_{it} + \beta_8 Urban_{it} + \beta_7 Density_{it} + \theta_{it} \quad (2)$$

where TB - includes TB incidence rate per 100,000 people (newly diagnosed cases over the course of the year t and TB prevalence per 100,000 people (number of people living with a TB diagnosis at the beginning of year t) in a raion; $Educ$ - share of employees with higher education; $Death$ - death rate in a raion as a measure of overall population health; $Unempl$ - unemployment rate; Exp - share of exports in total output; Imp - share of imports in total output; $Urban$ - share of urban population; $Density$ - population density.

3.2 TFP Estimation

Regional TFP is computed as follows. Consider a production technology of a single-product firm j at time t described by a production function

$$Y_{jt} = L_{jt}^{\alpha_l} K_{jt}^{\alpha_k} M_{jt}^{\alpha_m} \exp(\omega_{jt} + u_{jt}), \quad (3)$$

where Y_{jt} units of real output are produced using L_{jt} units of labor, K_{jt} units of capital, deflated by producer-price deflator, and M_{jt} units of material inputs. ω_{jt} is firm-specific productivity, unobservable by an econometrician, but known to the firm before it chooses variable inputs. It includes, among other things, unobserved characterisitcs of the labor force, such as human capital, entrepreneurial talent, and health. We elaborate on this further in the paper. u_{jt} is idiosyncratic shock to production that also captures a measurement error. Y_{jt} is not observable, because we do not know firm-specific prices, p_{jt}. Sales, $R_{jt} = p_{jt}Y_{jt}$, are known. To filter out demand shocks from productivity measure, we introduce a constant elasticity of substitution demand system and estimate 3 by Olley & Pakes (1996), taking into account the relationship between output and price (Loecker 2011). Firm-level TFP is computed as

$$TFP_{jt} = (\ln R_{jt} - \beta_L \ln L_{jt} - \beta_K \ln K_{jt} - \beta_M \ln M_{jt} - \beta_Y \ln Y_{gt}) \frac{\sigma_s}{\sigma_s + 1} \quad (4)$$

where $\beta_f = \frac{\sigma_s+1}{\sigma_s}\alpha_f$, for $f = \{l, k, m\}$, σ_s is elasticity of substitution, and Y_{gt} is total output of industry g, where firm j operates. Details on the TFP estimation can be found in Shepotylo & Vakhitov (2012). Furthermore, firm level TFP estimates are aggregated to the level of region as given by

$$TFP_{it} = \sum_{jt \in i} w_{jt} TFP_{jt} \quad (5)$$

where w_{jt} is share of firm's j employment in the total employment in the region i, and TFP_{jt} is TFP of firm i. It may be argued that regional variation in TFP is driven by differences in economic structure across regions rather then due to firm and individual level differences. To address this issue, we also computed sector specific TFP as given by

$$TFP_{k,it} = \sum_{jt \in i,k} w_{jt} TFP_{jt} \tag{6}$$

where $k = agriculture, industry, services$

3.3 Spatial Determinants of Productivity and TB

In order to account for possible spillovers from TB in the neighboring regions to total factor productivity, which may arise due to commuting and spatial spread of the disease, we augment the models by adding a spatial dimension. We account for cross-region effects by specifying spatial weighting matrix W and adding spatial lags of our variable of interest as follows:

$$\begin{aligned} \ln ARW_{it} = \alpha_0 + \alpha_1 \ln TB_{it} + \alpha_1^W W * \ln TB_{it} + \alpha_2 Educ_{it} + \alpha_3 Educ_{it}^2 \\ + \alpha_4 \ln Death_{it} + \alpha_5 Unempl_{it} + \alpha_6 Urban_{it} + \alpha_7 Density_{it} + u_{it} \end{aligned} \tag{7}$$

$$\begin{aligned} \ln TFP_{it} = \beta_0 + \beta_1 \ln TB_{it} + \beta_1^W W * \ln TB_{it} + \beta_2 Educ_{it} + \beta_3 Educ_{it}^2 \\ + \beta_4 \ln Death_{it} + \beta_5 Unempl_{it} + \beta_6 Exp_{it} + \beta_7 Imp_{it} + \beta_8 Urban_{it} \\ + \beta_7 Density_{it} + u_{it} \end{aligned} \tag{8}$$

where W is a contiguity-based $I \times I$ spatial weighting matrix, and I is the number of regions. It's diagonal elements are equal to zero. An off-diagonal element, w_{ij} is positive if and only if regions i and j share a common border. All neighbors are equally important and the elements of the weighting matrix are raw-normalized, so $\sum_{j=1}^{R} w_{ij} = 1$, $\forall i = 1...R$. As a result for any TB related variable tb in TB, a spatial lag of TB, expressed as $W * TB$ is interpreted as a simple average of TB in all neighboring regions. We assume that an element of the error term has the following structure $u_{it} = u_i + \varepsilon_{it}$, where u_i is a time-invariant regional effect, and ε_{it} is an idiosyncratic shock in region i at time t. Equations (8) and (7) can be estimated by standard methods with regional fixed effects. The interpretation of the coefficients on spatial terms is straightforward. If TB measure in all neighboring regions increases by 1 percent, then ARW and TFP in region i increases by α_1^W and β_1^W percent respectively.

This model may suffer from mis-specification, due to the presence of other spatial effects, which, if omitted, are subsumed as part of the error term and correlate with the included spatial variables. In order to account for such effects, we introduce a spatial Durbin model (Anselin 1988). It adds a spatial lag of the dependent variable, Wy, as one of the controls:

$$\begin{aligned}\ln ARW_{it} = \alpha_0 + \alpha_1 \ln TB_{it} + \alpha_1^W W * \ln TB_{it} + \alpha_2 Educ_{it} + \alpha_3 Educ_{it}^2 \\ + \alpha_4 \ln Death_{it} + \alpha_5 Unempl_{it} + \alpha_6 Urban_{it} + \alpha_7 Density_{it} \\ + \rho * W * \ln ARW_{it} + u_{it} \quad (9)\end{aligned}$$

$$\ln TFP_{it} = \beta_0 + \beta_1 \ln TB_{it} + \beta_1^W W * \ln TB_{it} + \beta_2 Educ_{it} + \beta_3 Educ_{it}^2$$
$$+ \beta_4 \ln Death_{it} + \beta_5 Unempl_{it} + \beta_6 Exp_{it} + \beta_7 Imp_{it} + \beta_8 Urban_{it}$$
$$+ \beta_7 Density_{it} + \lambda * W * \ln TFP_{it} + u_{it} \quad (10)$$

where ρ and λ are estimated spatial lag coefficients. The spatial lag variable Wy is endogenous variable. In order to estimate this model, we use the instrumental variable approach, where the spatial lag of the dependent variable is instrumented by the spatial lags of all right-hand side exogenous variables (Kelejian & Prucha 1998).

4 Data and Descriptive Analysis

We are using raion-level data routinely collected by the Ukrainian Oblast Centers of Statistics for the period from 2003 to 2009. Table 1 provides information on the average sample characteristics across time with each column providing information on current productivity and TB measures and other control variables. As can be seen, both average regional wage (in 2001 constant prices) and the total factor productivity has been increasing over the considered period. The TB prevalence per 100,000 population has been decreasing, while the incidence rate has peaked in 2006 and then fell by the end of the period.

Figure 1 presents the dynamics of the key indicators, and Figures 2-5 – maps for year 2009 for TB measures and outcome variables at the start and the end of the period.

4.1 Total Factor Productivity and Average Regional Wage

Total factor productivity for a region is the labor weighted-average TFP across all firms in the region. Firm level TFP are recovered from the production functions estimated separately for each manufacturing and service industry (1-digit NACE classification) using Olley-Pakes procedure (Olley & Pakes 1996) controlling for sub-industry-specific demand and price shocks (Loecker 2011). The data for the study come from several statistical statements annually submitted to the Ukrainian Statistics Service (Derzhkomstat) by all commercial firms in 22 manufacturing industries and 15 service subsectors.

The data on average regional wage is routinely collected by the State Statistics Service from all the enterprises of all forms of ownership, including the agricultural sector (which is not accounted for in the TFP). Self-employed people and statistically small enterprises are not taken into account by both measures.

5 Estimation Results

5.1 Impact of TB on Individual Productivity

Results in Table 2 confirm a detrimental impact of the TB epidemic on average individual productivity in rajon. Specifically, decrease in wage constitutes 4.2% for 10% higher TB prevalence, controlling for other factors in the fixed effects model. The share of employees with higher education has positive but diminishing effect on wage. This is consistent with the previous findings about diminishing returns to education in Ukraine. Death rate as a measure of the overall population health is positively associated with the average wage in the model when we control for rajon fixed effects, which can point to the risks and corresponding compensating wage differentials. The unemployment rate is negatively associated with the average wage, which is consistent with Efficiency Wage model, and urbanization has a positive impact, while population density - a negative effect.

However, higher average wage is associated with a corresponding "compensation" for the threat to health. Controlling for the TB prevalence, i.e. the number of TB diagnosed individuals, the TB incidence rate as a measure of the number of individuals who got infected over the course of a specific year is considered to be a measure of risk which has to be compensated to attract and/or retain individuals in a corresponding rajon. A 10% higher incidence rate of TB is associated with a 0.7% higher average regional wage in the rajon.

5.2 Impact of TB on the Productivity of Firms

The spread of TB appears to be damaging for the manufacturing firms as well, but the effect is moderate - 10% higher TB prevalence is associated with 1.2% lower TFP in the region. At the same time higher incidence rate has a positive and significant effect when we control for rajon fixed effects. In this case, the same 10% increase in the TB incidence rate is associated with a 0.6% higher total factor productivity. The negative effect of prevalence rates hold if we look at productivity at sectoral level. 10% increase in prevalence is associated with 6.6% lower productivity in agriculture, 4.7% - in industry, and 5.6% - in services.

5.3 Spatial effects

Table 3 presents results of a spatial model with the spatial lags of TB. It shows that in general, TB in the neighboring regions have similar effect on both wages and productivity as TB in the region itself. Once we control for other spatial effects, by estimating the spatial Durbin model, we have similar results for wages, but slightly less robust results for productivity.

5.4 Discussion

Table 7 provides an example of calculation of the overall country wide benefits of containing the TB epidemic in terms of productivity at individual and firm level. The calculations are provided using the country level data on GDP, the number of employed individuals and the average monthly wage rate. Applying the estimated wage and TFP elasicities with respect to the TB prevalence to the 2014 figures shows that a 10% reduction in TB prevalence would result into a 1.95% increase in GDP via an increase in TFP and 1.25% increase in GDP via higher individual productivity as measured by average monthly wages. The numbers are 2.06% and 1.25% respectively for year 2009.

6 Conclusions

This study relies on two unique data sets which allow combining epidemiological data on TB-related indicators with the socio-economic information from administrative statistics for small administrative units (rajons) in Ukraine to estimate the cost of TB epidemics. Out of the overall 669 rajons, the resulting analytical sample contains 592 over the period from 2003 to 2009. Using lagged values of measures describing TB epidemics (prevalence and incidence of the diseases) and applying fixed effects approach we find that indeed the ongoing TB epidemic has considerable indirect economic costs in terms of lost productivity and related inefficiencies. First of all, both firms and individuals in regions with higher TB prevalence have significantly lower TFP and wages. For example, an increase in TB prevalence rate by 10 percent leads to a 4.2% decrease in wages and 1.2% lower total factor productivity. Moreover, consistent with the Compensating Wage Differentials theory and after controlling for the prevalence of the TB, the risk of contracting the disease - TB incidence rate - is associated with higher wages and higher productivity - a kind of premium for individuals and firms to operate in risky environment. The latter can also be viewed as a source of inefficiency as this may prevent firms from entering more competitive markets. Additional analysis reveals strong spatial effects which are consistent with the infectious nature of the diseases and emphasize the importance of containing the epidemic.

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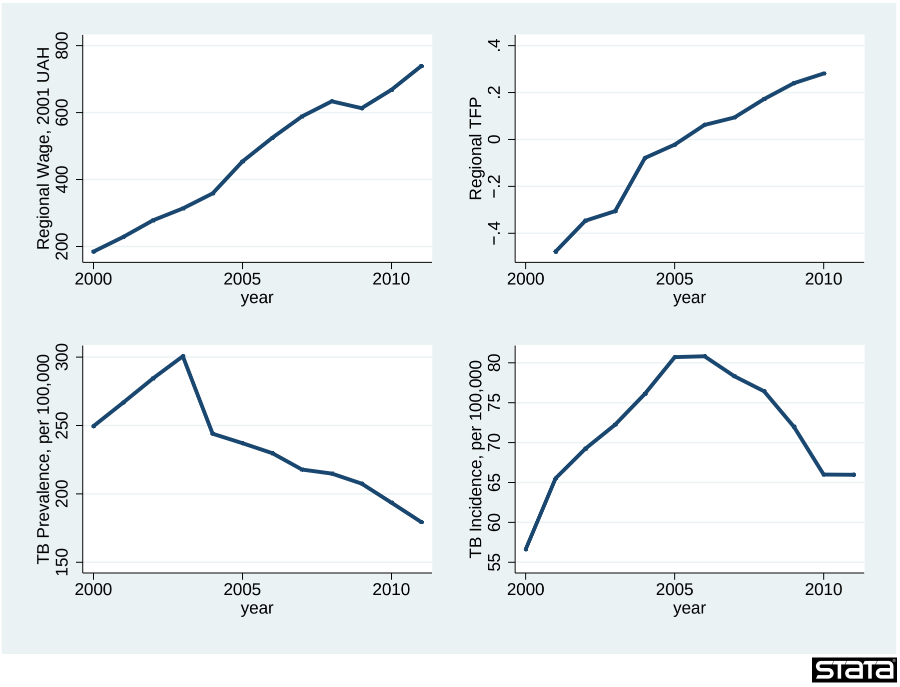

Figure 1: Time Dynamics: Measures of Productivity and TB.

Figure 2: Regional Variation in TB Prevalence, 2003 vs. 2009.

Figure 3: Regional Variation in TB Incidence, 2003 vs. 2009.

Figure 4: Regional Variation in Average Wage, 2003 vs. 2009.

Figure 5: Regional Variation in Residual TFP, 2003 vs. 2009.

Table 1: Descriptive statistics

	2003	2004	2005	2006	2007	2008	2009	Total
Average regional wage, 2001 UAH	312.87	357.94	453.85	527.66	594.60	638.62	617.28	498.38
	[137.27]	[138.29]	[154.71]	[158.33]	[165.33]	[156.82]	[145.61]	[192.12]
Average regional TFP (weighted)	-0.32	-0.08	-0.03	0.06	0.10	0.17	0.25	0.02
	[0.31]	[0.29]	[0.27]	[0.26]	[0.26]	[0.23]	[0.25]	[0.32]
TB prevalence (per 100,000)	299.63	245.49	237.91	230.05	217.47	211.91	204.35	235.44
	[98.86]	[85.83]	[83.03]	[75.10]	[73.15]	[72.54]	[69.27]	[85.34]
TB incidence (per 100,000)	71.76	75.99	80.70	81.10	78.17	75.86	71.39	76.55
	[29.61]	[33.58]	[31.67]	[32.61]	[30.85]	[31.16]	[27.07]	[31.24]
Death rate (per 1,000)	18.83	18.55	19.30	18.99	19.09	18.90	17.95	18.82
	[3.91]	[4.19]	[4.33]	[3.96]	[4.17]	[4.34]	[4.09]	[4.16]
Workers with higher education, %	17.34	18.4	19.66	20.71	23.57	25.22	27.09	21.62
	[5.43]	[5.81]	[5.97]	[5.96]	[7.69]	[8.21]	[8.72]	[7.66]
Unemployment rate, %	5.47	5.65	5.25	4.61	4.03	5.30	3.11	4.79
	[3.24]	[3.28]	[3.05]	[2.79]	[2.45]	[2.63]	[1.60]	[2.91]
Urban population, %	44.18	43.73	44.1	44.37	45.52	42.17	42.07	43.79
	[31.04]	[31.00]	[31.02]	[30.87]	[31.49]	[29.34]	[29.23]	[30.61]
Population density	441.67	439.93	441.84	442.99	442.84	402.9	393.9	430.33
	[1049.14]	[1048.84]	[1049.34]	[1051.48]	[1007.71]	[990.72]	[979.16]	[1025.86]
Prison	0.22	0.21	0.21	0.22	0.21	0.19	0.20	0.21
	[0.41]	[0.41]	[0.41]	[0.41]	[0.41]	[0.40]	[0.40]	[0.41]
N obs	493	530	529	519	541	472	471	3555

Note: Standard deviations in brackets.

Table 2: Estimated Effect of TB-incidence and TB-prevalence on Weighted Average Regional TFP Growth and Average Regional Wage Growth

	Regional Wage		Residual Regional TFP		Residual Regional TFP - FE		
	OLS	FE	OLS	FE	Agr	Man	Serv
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log of TB incidence	0.0438*	0.0548**	0.0423*	0.0506**	0.034	-0.0021	0.1338
	(0.0171)	(0.0095)	(0.0185)	(0.0148)	-0.0755	(0.1298)	-0.359
Log of TB prevalence	-0.0098	-0.0333*	-0.0467+	-0.0893**	0.0991	-0.0122	-0.0811
	(0.0260)	(0.0148)	(0.0272)	(0.0187)	-0.1273	(0.1760)	-0.2945
Log of Death Rate	-0.1212*	0.6259**	-0.0675	0.0846	-0.9345**	0.5343	1.7950+
	(0.0512)	(0.0490)	(0.0502)	(0.0695)	(0.3020)	(0.6631)	(0.9206)
% Emp with HE	0.0073**	0.0071*	0.0018	-0.0017	0.0110	-0.0139	-0.0638
	(0.0024)	(0.0034)	(0.0027)	(0.0029)	(0.0131)	(0.0298)	(0.0494)
% Emp with HE, squared	-0.0001**	-0.0001**	-0.0000	0.0001	-0.0001	-0.0000	0.0008+
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0005)	(0.0005)
Unemployment	-0.0191**	0.0074**	-0.0051	0.0006	0.0001	0.0151	-0.0933
	(0.0027)	(0.0017)	(0.0033)	(0.0026)	(0.0124)	(0.0242)	(0.0640)
Urban Population	0.0040**	0.0008	-0.0013*	0.0009	-0.0057	-0.0015	0.5173*
	(0.0004)	(0.0008)	(0.0006)	(0.0015)	(0.0046)	(0.0043)	(0.2072)
Population density	0.0000	0.0001	0.0000	0.0003	0.0021*	0.0001	-0.0008**
	(0.0000)	(0.0001)	(0.0000)	(0.0003)	(0.0009)	(0.0004)	(0.0002)
Export share			-0.0221	-0.0130	-0.1677	0.4197	-0.5503
			(0.0593)	(0.0629)	(0.2200)	(0.3021)	(0.8000)
Import share			0.0083	-0.0404	-0.1239	0.2805*	0.5834
			(0.0504)	(0.0363)	(0.1049)	(0.1385)	(0.6492)
Prison*year	0.0008	-0.0181**	0.0062+	-0.0194**	-0.0665*	0.0445	0.1141
	(0.0033)	(0.0036)	(0.0037)	(0.0046)	(0.0285)	(0.0385)	(0.0699)
Year	0.1235**	0.1408**	0.0771**	0.0810**	0.3137**	0.1621**	0.0111
	(0.0036)	(0.0039)	(0.0042)	(0.0032)	(0.0179)	(0.0253)	(0.0736)
Constant	-241.6447**	-278.4420**	-154.2850**	-162.4863**	-629.3732**	-328.3743**	-58.5966
	(7.3674)	(7.9130)	(8.3469)	(6.4620)	(36.0297)	(51.0530)	(141.9271)
Number of Observations	3,555	3,555	3,555	3,555	2,340	1,745	817
R-squared/F-stat	0.6922	941.49	0.2825	179.62	62.72	8.14	6.13
Number of id		609		609	562	504	311

Note: Robust standard errors in parentheses ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$

Table 3: Estimated Own and Spatial Effects of TB-incidence and TB-prevalence on Productivity

	Regional Wage	Residual Regional TFP - FE			
		Overall	Agr	Man	Serv
	(1)	(2)	(3)	(4)	(5)
Log of TB incidence	0.0397**	0.0401**	0.0367	-0.0355	0.1395
	(0.0086)	(0.0124)	(0.0746)	(0.1201)	(0.2380)
Spatial lag (Log of TB incidence)	0.1221**	0.0838**	0.0327	0.2158	-0.0694
	(0.0127)	(0.0182)	(0.1288)	(0.1889)	(0.2894)
Log of TB prevalence	-0.0216+	-0.0757**	0.0842	0.0924	-0.0286
	(0.0122)	(0.0175)	(0.1166)	(0.1766)	(0.2896)
Spatial lag (Log of TB prevalence)	-0.0491**	-0.0608**	-0.0181	-0.4762**	-0.1595
	(0.0108)	(0.0154)	(0.1183)	(0.1659)	(0.2756)
Prison*year	-0.0184**	-0.0192**	-0.0579*	0.0520	0.1297*
	(0.0025)	(0.0035)	(0.0232)	(0.0335)	(0.0568)
Prison*year in neighbouring rajons	-0.0128**	-0.0246**	-0.1043*	-0.0909	-0.0123
	(0.0043)	(0.0062)	(0.0416)	(0.0592)	(0.0707)
Number of Observations	3,555	3,555	2,340	1,745	817
Number of id	609	609	562	504	311

Note: Robust standard errors in parentheses ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$

Table 4: Estimated Own and Spatial Effects of TB-incidence and TB-prevalence on Productivity, Spatial Durbin model

	Regional	Residual Regional TFP - FE			
	Wage	Overall	Agr	Man	Serv
	(1)	(2)	(3)	(4)	(5)
Spatial lag of dependent variable	0.5326**	1.1652**	-0.2726	-0.2373	-0.6147
	(0.0442)	(0.1765)	(0.1881)	(0.2674)	(0.4173)
Log of TB incidence	0.0143+	-0.0094	-0.0068	-0.0362	0.0641
	(0.0081)	(0.0150)	(0.0828)	(0.1223)	(0.2655)
Spatial lag (Log of TB incidence)	0.0613**	-0.0330	-0.0875	0.1945	0.0858
	(0.0126)	(0.0260)	(0.1570)	(0.1938)	(0.3338)
Log of TB prevalence	0.0135	0.0564*	0.1673	0.0956	0.0826
	(0.0115)	(0.0272)	(0.1337)	(0.1797)	(0.3257)
Spatial lag (Log of TB prevalence)	-0.0446**	0.0446*	0.0014	-0.4519**	-0.0808
	(0.0098)	(0.0227)	(0.1232)	(0.1710)	(0.3063)
Prison*year	-0.0187**	-0.0076+	-0.0671**	0.0468	0.1034
	(0.0022)	(0.0041)	(0.0249)	(0.0346)	(0.0647)
Prison*year in neighbouring rajons	-0.0041	-0.0056	-0.0854+	-0.0648	0.0440
	(0.0040)	(0.0071)	(0.0450)	(0.0670)	(0.0863)
Number of Observations	3,555	3,555	2,340	1,745	817
Number of id	609	609	562	504	311

Note: Robust standard errors in parentheses ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$

Table 5: Sensitivity Analysis with Regards to Specification

	Specification		
	Main	Main + industry	Main - education
	(1)	(2)	(3)
Regional Wage - FE			
Log of TB incidence	0.0548**	0.0419*	0.0545**
	(0.0095)	(0.0173)	(0.0096)
Log of TB prevalence	-0.0333*	-0.0451+	-0.0353*
	(0.0148)	(0.0256)	(0.0147)
Residual Regional TFP - FE			
Log of TB incidence	0.0507**	0.0513**	0.0494**
	(0.0148)	(0.0148)	(0.0151)
Log of TB prevalence	-0.0895**	-0.0896**	-0.0867**
	(0.0187)	(0.0188)	(0.0188)

Note: Robust standard errors in parentheses ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$

Table 6: Sensitivity Analysis with Different Approaches to TFP Measurement

	Residual Regional TFP - FE				
	rtfp	rtfp_op1	rtfp_op1_acf	rtfp_lp	rtfp_lp_acf
	(1)	(2)	(3)	(4)	(5)
Log of TB incidence	0.0506**	0.0504**	0.0493**	0.0517**	0.0484**
	(0.0148)	(0.0140)	(0.0138)	(0.0145)	(0.0141)
Log of TB prevalence	-0.0892**	-0.0971**	-0.0986**	-0.0932**	-0.0886**
	(0.0187)	(0.0177)	(0.0174)	(0.0188)	(0.0178)

Note: Robust standard errors in parentheses ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$

Table 7: Comparison of current expenditures on TB-related programs from all sources and individual productivity losses associated with a 10% increase in TB prevalence

	2014	2009
Gross Domestic Product (UAH)	1,586,900,000,000	947,042,000,000
Employment (persons)	18,073,300	20,191,500
Average monthly wage	3368	1906
Considered decrease in TB prevalence (%)	-10	-10
TFP elasticity with respect to TB prevalence	-0.0893	-0.0893
Wage elasticity with respect to TB prevalence	-0.0333	-0.0333
Total national wage bill	730,450,492,800	461,819,988,000
Gain from fighting TB in terms of wages (UAH)	2,432,400,141	1,537,860,560
Gain from Fighting TB in terms of wages (% of GDP)	0.15	0.16
Gain from fighting TB in terms of TFP (% of GDP)	0.89	0.89
Total gain from fighting TB (% of GDP)	1.05	1.06
TB-related expenditure (UAH)	568,836,440	n/a
TB-related expenditure (% of GDP)	0.04	